



This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

### Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

- + *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
- + *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
- + *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
- + *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

### About Google Book Search

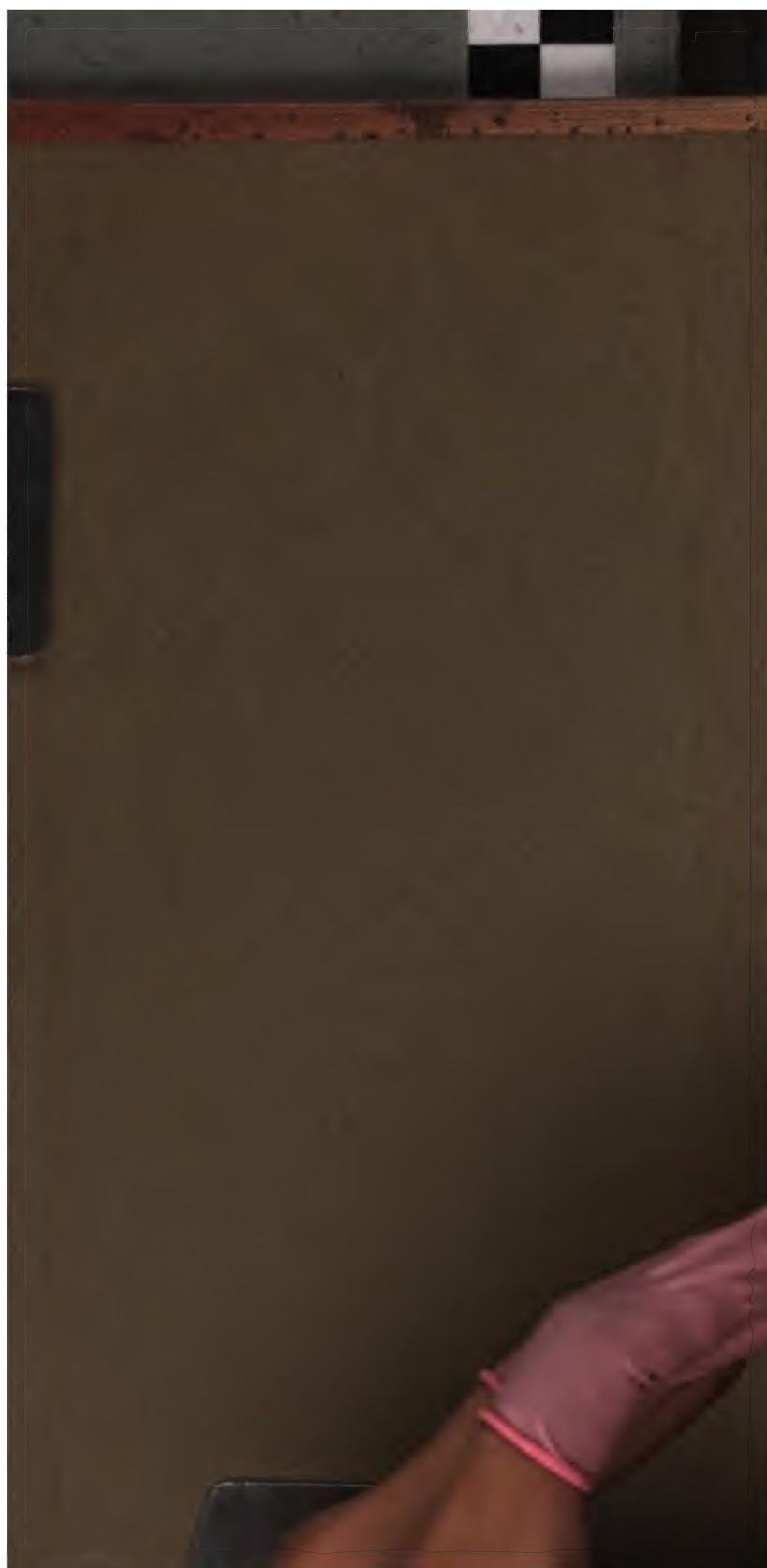
Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at <http://books.google.com/>

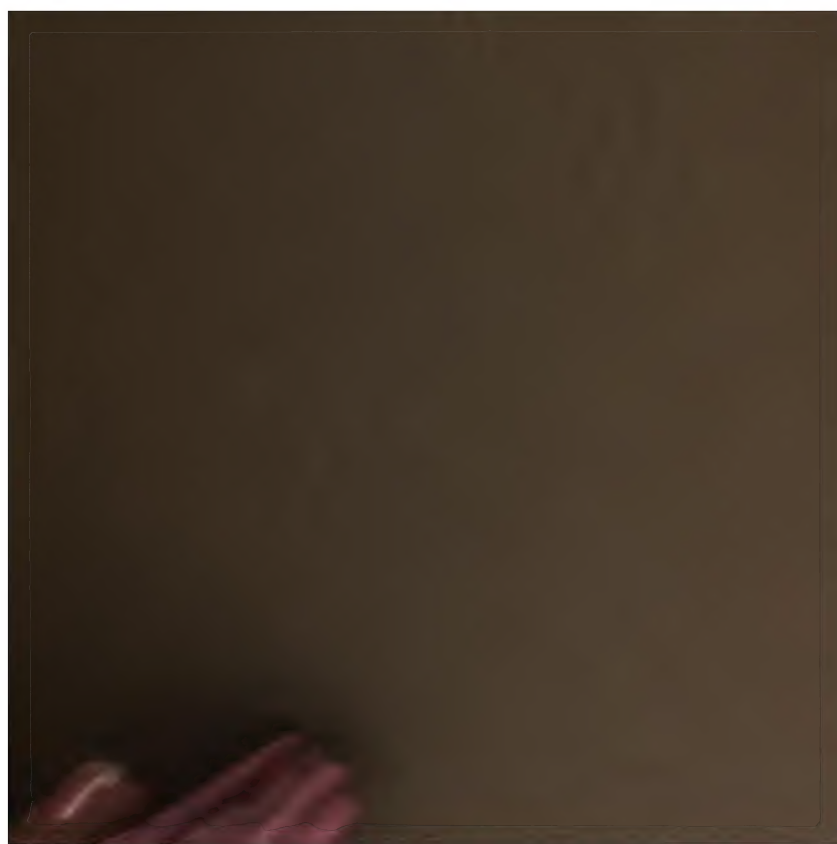
NYPL RESEARCH LIBRARIES



3 3433 06633231 7







1





**SYSTEM**  
**OF**  
**CHEMISTRY.**

**IN FIVE VOLUMES.**

---

**By THOMAS THOMSON,**  
**M. D. F. R. S. E.**

---

*THE FOURTH EDITION.*

**VOL. V.**

---

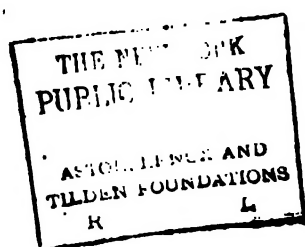
**EDINBURGH:**

**PRINTED FOR BELL & BRADFUTE.**

**SOLD BY JOHN MURRAY, LONDON; AND GILBERT & HODGES,  
DUBLIN.**

---

**1810.**



NOV 20 1994  
CLUB  
Y&A



# CONTENTS

OF

## VOLUME FIFTH.

---

	Page-
<b>BOOK IV. CHAP. I. of PART II. continued</b>	<b>1</b>
ECT 11. Of indigo - -	ib.
12. Of gluten - -	16
13. Of albumen - -	25
14. Of fibrin - -	29
15. Of bitter principle -	31
16. Of tannin - -	38
17. Of extractive - -	43
18. Of the narcotic principle	50
19. Of oils - -	55
20. Of wax - -	59
21. Of camphor - -	66
22. Of birdlime - -	78
23. Of resins - -	83
24. Of guaiacum - -	113
25. Of balsams - -	118
26. Of caoutchouc - -	131
27. Of gum resins - -	139
28. Of cotton - -	150
29. Of suber - -	153

	Page.
SECT. 30. Of wood - - -	154
31. Of alkalies - - -	158
32. Of earths - - -	162
33. Of metals - - -	172
34. Of vegetable principles in general - - -	173
CHAP. II. Of the parts of plants -	182
SECT. 1. Of the sap - - -	183
2. Of the peculiar juices	190
3. Of the wood and roots	196
4. Of barks - - -	210
5. Of leaves - - -	223
6. Of flowers - - -	231
7. Of pollen - - -	239
8. Of seeds - - -	243
9. Of fruits - - -	270
10. Of bulbs - - -	272
11. Of lichens - - -	281
12. Of mushrooms - -	286
13. Of the diseases of plants	291
CHAP. III. Of vegetation - - -	295
SECT. 1. Of germination - -	296
2. Of the food of plants	307
3. Of the motion of the sap	330
4. Of the functions of the leaves	347
5. Of the peculiar juices	374
6. Of the decay of plants	381
CHAP. IV. Of the décomposition of ve- getable substances - - -	384
SECT. 1. Of the panary fermentation	389
2. Of the vinous fermentation	397
3. Of the acetous fermentation	422
4. Of putrefaction - -	426



# CONTENTS.

vii

	Page.
<b>BOOK V. OF ANIMALS</b> - - -	<b>428</b>
<b>CHAP. I. Of animal substances</b> -	<b>430</b>
<b>SECT. 1. Of gelatine</b> - -	<b>ib.</b>
2. Of albumen - -	<b>441</b>
3. Of mucus - -	<b>456</b>
4. Of fibrin - -	<b>458</b>
5. Of urea - -	<b>463</b>
6. Of saccharine matter	<b>469</b>
7. Of oils - -	<b>472</b>
8. Of resins - -	<b>478</b>
9. Of sulphur and phosphorus	<b>486</b>
10. Of acids - -	<b>487</b>
11. Of alkalies, earths, and metals - -	<b>492</b>
12. Of animal principles in ge- neral - -	<b>493</b>
<b>CHAP. II. Of the parts of animals</b> -	<b>496</b>
<b>SECT. 1. Of bones, shells, and crusts</b>	<b>498</b>
2. Of horns, nails, and scales	<b>518</b>
3. Of muscles - -	<b>522</b>
4. Of skin - -	<b>528</b>
5. Of membranes, tendons, li- gaments, and glands	<b>535</b>
6. Of brain and nerves -	<b>537</b>
7. Of marrow - -	<b>541</b>
8. Of hair and feathers -	<b>545</b>
9. Of silk - -	<b>550</b>
10. Of blood - -	<b>555</b>
11. Of milk - -	<b>565</b>
12. Of eggs - -	<b>578</b>
13. Of saliva - -	<b>581</b>
14. Of bile - -	<b>584</b>
15. Of cerumen - -	<b>592</b>

	Page.
SECT. 16. Of tears and mucus -	594
17. Of the liquor of the pericardium - -	599
18. Of the humours of the eye	600
19. Of sinovia - -	603
20. Of semen - -	607
21. Of the liquor of the amnios	612
22. Of animal poisons -	617
23. Of air in the swimming bladders of fishes -	621
24. Of sweat - -	624
25. Of urine - -	630
26. Of feces - -	648
27. Of morbid concretions	658
28. Of morbid secretions	690
CHAP. III. Of the functions of animals	698
SECT. 1. Of digestion - -	699
2. Of respiration -	714
3. Of the action of the kidneys	740
4. Of perspiration -	742
5. Of assimilation -	748
CHAP. IV. Of the decomposition of animal bodies -	758
Appendix - - -	767

A  
SYSTEM  
OF  
CHEMISTRY.

---

BOOK IV. CHAPTER I. OF PART II.

CONTINUED.

---

SECT. XI.

OF INDIGO.

THIS valuable pigment, one of the capital manufactures of America, is obtained from the leaves of different species of plants; the *indigofera argentea* or wild indigo, which is said to yield the finest pigment, but in smallest quantity; the *indigofera disperma* or Guatimala indigo; and the *indigofera tinctoria* or French indigo, which yields the greatest quantity of indigo, and is therefore preferred by the planter, though its quality be inferior to the indigo obtained from the other

Vol. V.

A

Chap. I.

Book IV.  
Manufac-  
ture.

species \*. For the first accurate account of the mode of preparing indigo from these plants, we are indebted to Labat †. Since his time some improvements have been introduced into the manufacture; but the mode of rearing the plants still continues the same. In the West Indies the seeds are sown in March, in trenches about a foot asunder, and the plant comes into blossom, and is fit for cutting down in May; but in south America about six months elapse before it can be cut. In the West Indies four cuttings are often obtained from the same plant in the course of a year; but in America never more than two, and often only one. The produce continually diminishes after the first cutting; so that it is necessary to renew the plants from seed every year.

The plants are cut down with sickles, and laid in strata in the *steeper*, till it is about three parts full. This is a large cistern of mason work or wood about 16 feet square. Here they are pressed down with planks, and loaded to prevent them from swimming, and covered with water to the height of four or five inches. Here they ferment; and the utmost attention is required to the process. If they be allowed to remain too long, the pigment is spoiled; and if the water be drawn off too soon, much of the indigo is lost. This fermentation, according to Le Blond, goes on best at the temperature of 80°. The water soon becomes opaque, and assumes a green colour; a smell resembling that of vo-

\* Edward's *History of the West Indies*, ii. 275.; and Berthollet, *Elements de la Teinture*, ii. 37.

† See his Account detailed by Dr Lewis in Neumann's *Chemistry* p. 433.



lative alkali is exhaled, and bubbles of carbonic acid are emitted\*. When the fermentation has continued long enough, the liquor is let out into a second cistern, placed lower than the first. This cistern is called the *battery*, and is commonly about 12 feet square and four and a half deep. Here it is agitated for 15 or 20 minutes by means of levers moved by machinery, till the flocculi, beginning to separate, give it a curdled appearance. A quantity of lime water is now poured in, and the blue flocculi are allowed to subside. The lime-water is supposed to prevent putrefaction, which otherwise might endanger the pigment; and according to Le Blond, it absorbs carbonic acid, which existed in the liquid, and prevented the indigo from separating. The water is drawn off, and the pigment put to be drained in small linen bags; after which it is put into little square boxes, and allowed to dry in the shade†.

Europe was long supplied with indigo from the West Indies and America; but of late the manufacture has been introduced into Indostan, and carried on with such spirit and success as promises fair to secure to that country in future the supply of the European market‡.

The leaves of the *indigofera* yield a green infusion to hot water, and a green powder may be precipitated from it; but unless a fermentation has taken place, neither the colour nor properties of it have any resemblance to indigo. Le Blond affirms that the contact of air is necessary to the fermentation of indigo; but his proofs are insufficient. The separation of carbonic acid

\* *Jour. de Phys.* xxviii. 141.

† *Edward's History of the West Indies*, ii. 278.

‡ See *Tenant's Indian Revenues*, ii. 142.

Book IV.

is a sufficient proof that chemical decompositions are going on during the fermentation ; but of what nature we are ignorant.

The *indigofera* is not the only genus of plants from which indigo may be obtained. Dr. Roxburgh first drew the attention of manufacturers to the *sericium tinctorium*, a tree very common in Indostan, from the leaves of which it may be extracted in abundance. His process is shorter. The leaves are kept in a copper full of water, supported at the temperature of 160°, till they assume a yellowish hue, and the liquid acquire a deep green colour. The liquid is then drawn off, agitated in the usual manner, and the indigo thrown down by lime water \*.

Indigo may be obtained also from the *isatis tinctoria*, or woad ; a plant commonly enough cultivated in Britain, and even found wild in England †. When arrived at maturity, this plant is cut down, washed, dried hastily in the sun, ground in a mill, placed in heaps, and allowed to ferment for a fortnight. It is then well mixed, and made up into balls, which are piled upon each other, and exposed to the wind and sun. In this state they become hot, and exhale a putrid ammoniacal smell. The fermentation is promoted, if necessary, by sprinkling the balls with water. When it has continued for a sufficient time, the woad is allowed to fall to a coarse powder ; in which state it is sold as a dye-stuff. By treating woad nearly in the same manner with the *indigofera*, indigo has been obtained from it

---

\* Bancroft on *Permanent Colours*, p. 423.

† Some think that this is the plant with which the ancient Britons stained their bodies, to make them appear terrible to their enemies.

by different chemists. Justi\* was one of the first of these. Borth published a paper on the subject in 1754†, Kulencamp‡ in 1755, and Edel§ a third in 1756. Chap. I.

Chevreul obtained, by digesting *woad* in alcohol, and evaporating the solution, *white* crystalline grains, which gradually became blue when exposed to the atmosphere, and assumed the usual appearance of indigo. These white grains he considers as indigo destitute of oxygen. Their crystallized state is remarkable ||.

The method of preparing indigo, and of applying it to the purposes of dyeing, seems to have been very early known in India; but in Europe, though it had been occasionally used as a paint ¶, its importance as a dye-stuff was not understood before the middle of the 16th century. It is not even mentioned in the *Plictho*, a celebrated work on dyeing published in Italy in 1548. The Dutch were the people who first imported it from India, and made its importance known in Europe. Even as late as the middle of the seventeenth century, its use was restricted in different countries. It was prohibited in England during the reign of Queen Elizabeth; and the prohibition was not taken off till the reign of Charles II. It was prohibited also in Saxony. In the edict it is spoken of as a corrosive substance, and called *food for the Devil*. Colbert restricted the French dyers to a certain quantity of it \*\*. Soon after its importance began to be generally understood, it was History.

\* Schreber's *Sammlungen*, i. 68.

† In the *Halle Newspaper*.

‡ Schreber's *Samml.* viii. 448.

§ *De Indo Germanico ex Glasse*.

¶ *Jour. de Phys.* lxxvi. 373.

¶ Plinii, Lib. xxv. c. 6.

\*\* See Dapcroff on *Permanent Colours*, and Berthollet on *Dyeing*.

## INGREDIENTS OF PLANTS.

**Book IV.** cultivated in Mexico and the West Indies with success that the indigo from these countries was preferred to every other: but within these few years the Indian indigo, owing entirely to the enlightened exertions of some of our own countrymen, has recovered its former character, and is now imported in considerable quantities to Britain.

**Properties.** Indigo is a fine light friable substance of a deep blue colour. Its texture is very compact, and the shape of its surface varies according to the manner in which it has been prepared. The principal tints are copper, yellow, and blue; the lightest indigo is the best: but it is always more or less mixed with foreign substance, probably owing, doubtless to the carelessness of the preparation, and partly to the bodies which the plant containing indigo yields to water. From the analysis of Bergman, to whom we are indebted for one of the most complete treatises on the properties of indigo which has yet appeared, the purest indigo which he could procure was composed of the following constituents:

47 pure indigo
12 gum
6 resin
22 earth
13 oxide of iron

100 \*

The earth consisted of 10.2 barytes

10.0 lime
1.8 silica

22.0 †

---

\* Bergman, v. 36.

† Ibid. v. 33.



But in all probability the earth differs in different specimens; for Proust found magnesia in considerable quantity in the specimens which he examined\*. The 47 parts of blue pigment are alone entitled to the name of indigo; and to them therefore we shall confine our attention in this Section.

Chevreul has lately published the result of his experiments on Guatemala indigo, which shows that the indigo of commerce is a still more complex substance than Bergman found it.

Hot water digested on indigo became yellow. This liquid being distilled gave out ammonia and let fall a greenish matter which became blue upon exposure to the air, and possessed the properties of indigo. After this matter has separated, flocks precipitated of a green colour, to which Chevreul has given the name of *green matter*. It is scarcely soluble in water, but dissolves in alkaline leys and becomes reddish. When the alkali is saturated by an acid the colour becomes green, and when the liquid is concentrated the green matter precipitates in flocks. Alcohol dissolves it and becomes reddish; but when spread thin upon any substance it still looks green. Alcohol being poured into the water from which the green matter had precipitated, a substance fell of a brownish yellow colour and a bitter and astringent taste, and which burnt on coals, emitting the odour of empyreumatic vinegar.

Constitu-  
ents of com-  
mon indigo.

The indigo thus treated was digested in alcohol. The alcohol dissolved; 1. *green matter*; 2. *red matter*; 3. *indigo*. The *red matter* agrees with the *green* in all

---

\* Nicholson's Journal, iii. 325.

## INGREDIENTS OF PLANTS.

Book IV.

its properties except colour. The colour does change by solution in alkaline leys and alcohol.

The indigo in the third place was treated with nitric acid which dissolved 1. *iron* ; 2. *carbonate of lime* ; 3. *red matter*.

The following Table exhibits the substances taken from Guatimala indigo by these processes, and of course its composition.

Water	{ ammonia	
	{ disoxygenized indigo...	12
	{ green matter	
	{ bitter matter	
Alcohol.	{ green matter.....	30
	{ red matter	
	{ indigo	
Muriatic acid	{ red matter .....	6
	{ carbonate of lime .....	2
	{ oxide of iron and alumina	2
	{ silica.....	3
	{ pure indigo.....	45

Total 100

All indigos do not yield the same substances nor in the same proportions. In some the *green matter* has a brown colour \*.

Action of  
water.

Indigo is a soft powder, of a deep blue inclining to purple, without either taste or smell. It undergoes no change though kept exposed to the air. Water does not dissolve any part of it, nor produce any change in it. Bergman however found, that indigo, when long under water, underwent a kind of putrefaction.

---

\* Chevreul, *Jour. de Phys.* lxx. 309.

at least exhaled a fetid odour\*. When heat is applied to indigo it emits a bluish red smoke, and at last burns away with a very faint white flame, leaving behind it the earthy parts in the state of ashes†. The purple smoke, as Chevreul ascertained, crystallizes in needles, and is indigo unaltered.

Chap. I.

Neither oxygen nor the simple combustibles have any effect upon indigo, except it be in a state of solution; and the same remark applies to the metallic bodies.

The fixed alkaline solutions have no action on indigo, except it be newly precipitated from a state of solution. In that case they dissolve it with facility. The solution has at first a green colour, which gradually disappears, and the natural colour of the indigo cannot be again restored. Hence we see, that the alkalis when concentrated decompose indigo‡. Pure liquid ammonia acts in the same way. Even carbonate of ammonia dissolves precipitated indigo, and destroys its colour; but the fixed alkaline carbonates have no such effect§.

Lime-water has scarcely any effect upon indigo in its usual state; but it readily dissolves precipitated indigo. The solution is at first green, but becomes gradually yellow. When the solution is exposed to the air, a slight green colour returns, as happens to the solution of indigo in ammonia; but it soon disappears||. The effect of the other alkaline earths upon indigo has not hitherto been tried; but it cannot be doubted that they would act nearly as lime-water, but with more

\* *Opus*, v. 29.

† *Ibid.*

‡ *Ibid.* p. 38.

§ *Ibid.* 25.

|| *Ibid.* v. 24.

Book IV. **energy.** The other earths seem to have but little action on indigo in any state.

**Acids.** The action of the acids upon indigo has been examined with most attention, and it certainly exhibits the most important phenomena.

**Sulphuric acid.** When diluted sulphuric acid is digested over indigo, it produces no effect except that of dissolving the impurities; but concentrated sulphuric acid dissolves it readily. One part of indigo, when mixed with eight parts of sulphuric acid, evolves heat, and is dissolved in about 24 hours. The solution of indigo is well known in this country by the name of *liquid blue*. Bancroft calls it *sulphate of indigo*. While concentrated, it is opaque and black; but when diluted, it assumes a fine deep blue colour, and its intensity is such, that a single drop of the concentrated sulphate is sufficient to give a blue colour to many pounds of water †.

**Effect of reagents on the sulphate.** Bergman ascertained the effect of different reagents on this solution with great precision. His experiments threw light, not only on the properties of indigo, but upon the phenomena that take place when it is used as a dye-stuff. The following is the sum of these experiments:

1. Dropt into diluted water. No change.
2. Dropt into sulphurous acid. Colour at first blue, then green, and very speedily destroyed.
3. In weak nitric acid it experiences no change.
4. In muriatic acid. No change.
5. In weak tartaric acid. Becomes gradually green,

---

\* *Opusc.* v. 25.

† Bergman, v. 7.

ind in 144 hours had assumed a very pale yellow colour. Colour not restored by alkalies.

6. In vinegar. Becomes green, and in four weeks the colour disappeared.

7. In weak potash. Becomes green and then colourless.

8. In weak carbonate of potash. The same changes, but more slowly. If the solution be very weak, the colour of the indigo is not destroyed.

9. Soda. The same as potash.

10. In ammonia and its carbonate. Colour becomes green, and then disappears.

11. In a weak solution of sulphate of soda. Colour after some weeks becomes green.

12. In nitre, common salt, and sal ammoniac. No change.

13. In tartrate of potash. Became green and then colourless.

14. In a solution of sugar. Became green and at last yellowish.

15. In alum. No change.

16. In sulphate of copper. No change.

17. In sulphate of iron. Colour became green, and in three weeks disappeared.

18. In the sulphurets. Colour destroyed in a few hours.

19. Realgar, white oxide of arsenic, and orpiment, produced no change.

20. Black oxide of manganese destroyed the colour completely.

21. In the infusion of madder. Colour became green, and at last yellow.

## Book IV.

22. In the infusion of woad. The same changes, more speedily \*.

Blue colour  
of indigo  
owing to  
oxygen.

From these experiments, it is obvious that all the substances which have a very strong affinity for oxygen give a green colour to indigo, and at last destroy it. Hence it is extremely probable, that indigo becomes green by giving out oxygen. Of course it owes its blue colour to that principle. This theory was first suggested by Mr Haussman, and still farther confirmed by Berthollet†. Now it is only when green that it is in a state capable of being held in solution by lime, alkalies, &c. in which state it is applied as a dye to cloth. The cloth, when dipped into the vat containing it, is dissolved, combines with it, and the blue colour is restored by exposure to the atmosphere. It may be restored equally by plunging the cloth into oxymuriatic acid. Hence the restoration cannot but be ascribed to oxygen. Hence then the reason that sulphurous acid, the vegetable acids, sulphate of iron, give sulphate of indigo a green colour.

From these experiments, we see also that the blue colour of indigo is destroyed by the addition of those substances which part with oxygen very readily, as the black oxide of manganese. In that case the indigo is destroyed, for its colour cannot be again restored. When the sulphate of indigo is poured into boiling water, it forms a green-coloured solution; but with cold water a deep blue solution. What is called smoking sulphur

---

\* Bergman, v. 8.

† See *Jour. de Phys.* 1788; Berthollet's *Notes on Potner sur l'Art de Teindre*, p. 170; and Berthollet on *Dyeing*.



acid dissolves indigo much more readily than the pure acid, and evolves much more heat during the solution. Bucholz has shown, that by boiling sulphur in pure sulphuric acid, it acquires the property of dissolving indigo as readily as the smoking acid \*.

Chap. I.

Nitric acid attacks indigo with great violence; the evolution of abundance of heat and nitrous gas. When of the specific gravity 1.52, it even sets fire to indigo. This fact was discovered by Mr Woulfe. He communicated it to Rouelle, who exhibited it in his lectures. Sage first published an account of it †. When the acid is diluted, the action is still violent, unless the proportion of water be considerable. Mr Hatchett poured upon 100 grains of indigo an ounce of nitric acid diluted with an equal quantity of water. The action was so rapid, that he found it necessary to add another ounce of water. When the effervescence had nearly subsided, the liquid was placed on a sand bath for some days, and evaporated to dryness. Water poured upon the residuum dissolved a considerable portion of it, and formed a beautiful deep yellow solution of an intense bitter taste. This solution contains only a very small portion of oxalic acid; but with a solution of isinglass it forms a copious yellow insoluble precipitate, and of course contains a portion of artificial tannin. With ammonia, crystals precipitate, consisting of *bitter principle* combined with ammonia ‡.

Action of nitric acid.

Forms tannin.

When four parts of nitric acid are boiled upon one

Bitter principle.

\* Gehlen's Jour. iii. 1.

† Proust, Nicholson's Jour. iii. 328.

‡ Hatchett's Additional Experiments on Artificial Tannin, Phil. Trans. 1805.

Book IV.

part of indigo, the pigment soon loses its colour, and is dissolved. The solution becomes yellow, and a thin layer of a resinous matter appears on the surface. If the process be now stopt, the resinous matter becomes firm by cooling. If this matter be removed, and the solution evaporated to the consistence of honey, redissolved in hot water and filtered, potash throws down yellow spicular crystals, consisting of *bitter principle* combined with potash. These crystals have the curious property of detonating with a purple light when wrapt up in paper and struck with a hammer; the resin, by treating it with fresh nitric acid, may be converted into the same bitter principle. If the process be stopt sooner than the point mentioned above, yellow crystals are obtained, which are more soluble in water, and which sublime in white needles, having all the properties of benzoic acid. These curious facts were ascertained by Fourcroy and Vauquelin \*.

And benzoic acid,

Thus it appears, that by treating indigo with nitric acid, it is converted into tannin, oxalic acid, benzoic acid, and *bitter principle*.

Action of other acids,

Muriatic acid does not act upon indigo in its common state, but it readily dissolves indigo precipitated from the sulphate, and forms a blue-coloured solution. The same phenomena are exhibited by the phosphoric, acetic, tartaric acids, and probably by all except the acid supporters †.

Oxymuriatic acid destroys the colour of indigo as readily as nitric acid and obviously for the same reason ‡.

---

\* *Phil. M.g.* xxiii. 256.

† Bergman, v. 22.

‡ *Ibid.*



Alcohol dissolves a small proportion of indigo, but it gradually precipitates again unless *red matter* be present, in which case the solution is permanent \*.

Chap. I.

Indigo is not acted upon by ether or oils, at least if the experiments of Bergman be accurate †.

When indigo is mixed up with bran, woad, and other similar substances which readily undergo fermentation, it assumes a green colour during the fermentation, and is then easily dissolved by lime or potash. It is by this process that it is usually rendered proper for dyeing.

Fermentation.

When indigo is distilled, it yields products different from any other vegetable substance, if the accuracy of Bergman is to be trusted. He distilled 576 grains in a small retort connected with a pneumatic apparatus. He obtained the following products:

Action of heat.

29 grains carbonic acid gas

173 — of a yellow acid liquid containing ammonia

53 — oil

331 — charcoal

576 †

He observed no other gas but carbonic acid. The experiment ought to be repeated: if it prove true, no other vegetable substance agrees with it in this respect except gallic acid. The oil was black, and had the smell of tobacco. It dissolved readily in alcohol. The quantity of charcoal appears enormous; but Bergman's experiment was made with common indigo; therefore

\* Chevreul, *Jour. de Phys.* lxx. 309.

† *Opusc.* v. 51.

‡ Bergman, v. 35.

**Book IV.** 158 grains of earth and iron are to be subtracted from the sum. This decomposition indicates the presence of oxygen, carbon, hydrogen, and azote in indigo. The proportion of the two first constituents is uncommonly great.

Chevreul lately subjected common indigo to distillation. The products obtained were, 1. ammoniacal water. 2. Sulphur, probably combined with oily hydrogen. 3. A thick brown oil containing carbonate and acetate of ammonia. 4. Prussiate and hydrogureted sulphuret of ammonia. 5. A purple substance crystallized in silky threads on the dome of the retort. It was pure indigo. 6. A bulky charcoal yielding prussic acid when coloured with potash. 7. Gases not examined.

Such are the properties of indigo, as far as they have been ascertained. To descant on its importance is quite unnecessary. It is perhaps the most valuable, and certainly the most permanent, of all the dye-stuffs.

---

## SECT. XII.

### OF GLUTEN.

**Extraction.** **I**F wheat flour be kneaded into paste with a little water, it forms a tenacious, elastic, soft, ductile mass. This is to be washed cautiously, by kneading it under a small jet of water till the water no longer carries off

any thing, but runs off colourless ; what remains behind is called *gluten*. It was discovered by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat flour \*.

Properties.

1. Gluten, when thus obtained, is of a grey colour, exceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin, it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. In this state it adheres very tenaciously to other bodies, and has often been used to cement together broken pieces of porcelain. Its smell is peculiar. It has scarce any taste, and does not lose its tenacity in the mouth. When exposed to the air, it assumes a brown colour, and becomes as it were covered with a coat of oil.

When exposed to the air, it gradually dries ; and when completely dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*. It breaks like a piece of glass, and the edges of the fracture resemble in smoothness those of broken glass ; that is to say, it breaks with a *vitreous* fracture.

Soluble in water.

Fresh gluten imbibes water, and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

2. When fresh gluten is macerated for a considerable time in cold water, the liquid becomes opaque, and contains small films suspended, which do not soon subside. By repeated filtrations it becomes transparent ; but it

\* *Collect. Academ.* x. 1.

**Book IV.** holds in solution a little gluten, which renders it frothy, and gives it the property of precipitating when mixed with oxymuriatic acid or the infusion of nutgalls. Thus gluten is to a certain extent soluble in cold water. When the water is heated, the gluten separates in the state of yellow flakes\*.

Fermented  
gluten.

When kept moist, it very soon begins to decompose, and to undergo a species of fermentation. It swells, and emits air-bubbles, which Proust has ascertained to consist of hydrogen and carbonic acid gases†. It emits also a very offensive odour, similar to what is emitted by putrefying animal bodies. Cadet kept gluten in a vessel for a week in a damp room. Its surface became covered with byssi, the fermentation just mentioned had commenced, and the odour was distinctly acid. In 24 days, on removing the upper crust, the gluten was found converted into a kind of paste, of a greyish white colour, not unlike bird-lime. In that state he gave it the name of *fermented gluten*‡. If the gluten be still left to itself, it gradually acquires the smell and the taste of cheese. This curious fact was first ascertained by Rouelle junior. In that state it is full of holes, and contains the very same juices which distinguish some kinds of cheese. Proust ascertained that it contains ammonia and vinegar; bodies which Vauquelin detected in cheese: and ammonia robs both equally of their smell and flavour§.

---

\* Fourcroy and Vauquelin, *Annales de Mus. d'Hist. Nat.* No. xxxvii. p. 3.

† *Jour. de Phys.* lvi. 108.

‡ *Ann. de Chim.* xli. 315.

§ Proust, *Jour. de Phys.* lvi. 100.

Fourcroy and Vauquelin have examined the changes which gluten sustains when left for some months to putrify under water. When left in that liquor, at the temperature of  $54^{\circ}$ , it swells, becomes sour and fetid, and rises to the surface, giving out carbonic acid. The water acquires the property of giving out a red colour to paper stained with litmus. The fixed alkalies disengage ammonia, and oxymuriatic acid and infusion of nutgalls throw down a precipitate, indicating the presence of gluten in solution. When sugar is dissolved in this water, the liquid assumes the properties of vinegar, without fermentation or contact of the atmosphere. If the gluten be put again into water at the same temperature, the fermentation goes on, carbonic acid is disengaged, and the liquid slightly reddens litmus paper. The reagents indicate the presence of gluten and ammonia. The gluten, which forms a pellicle on the surface of the liquid, becomes first purple coloured, and then blackish grey, and exhales the fetid odour of putrefying mucous membranes. The water is now blackish; it gives a brown colour to nitrate of silver, blackens nitrate of mercury, becomes milky, and loses its smell when mixed with oxymuriatic acid, and is not precipitated by infusion of nutgalls. After three months putrefaction, the gluten was greatly diminished; it had a brown colour, and exhaled only a weak smell. When dried it formed lumps, which emitted the odour of the earth from a burial ground. They softened under the fingers, and burned like fat. In alcohol it partly dissolved, leaving behind it a substance which resembled woody fibre in its properties \*. Thus by putrefac-

---

\* *Ann. de Mus. d'Hist. Nat.* No. xxivû. 4.



## Book IV.

Action of  
alcohol.

tion gluten is converted into *carbonic acid*; *ammonia*, a *fatty matter*, and a substance analogous to *woody fibre*.

3. Fresh gluten does not sensibly dissolve in alcohol, which even throws down fresh gluten from water; yet in certain cases this liquid forms a solution of gluten in very small proportion. I poured two ounces of alcohol, of the specific gravity 0.837, upon 100 grains of pearl barley ground to a coarse powder, and allowed it to stand untouched for two years. On evaporating the liquid, it left behind it a yellow matter, which partly resembled an oil. Alcohol digested upon this substance took up the yellow matter and left *gluten*, easily recognizable by its properties. On trying the same experiment with wheat flour, no gluten was taken up, but only a yellow matter, which possessed the properties of *bitter principle*.

When the *fermented* gluten of Cadet is triturated with a little alcohol into a mucilage, and then mixed with a sufficient quantity of that liquid, a portion of it is dissolved. This solution constitutes an excellent varnish, possessed of considerable elasticity. It may be spread over paper or wood; and when dry resists other bodies as well as most varnishes. In this state, too, it may be employed to cement china; and triturated with paints, especially vegetable colours, it forms a very good ground. When this solution is mixed with a sufficient quantity of lime, it forms a very good lute; and bits of linen dipt in it adhere very strongly to other bodies\*.

4. Ether does not sensibly dissolve gluten.

---

\* Cadet, *Ann. de Chim.* xli. 316.

5. Acids act upon gluten differently according to the peculiar properties of each.

Chap. I.  
Acids,

Concentrated acetic acid dissolves it readily in considerable quantity, and without altering its nature. The solution is muddy, but permanent; and the gluten may be thrown down by means of alkalies. This acid dissolves the fermented gluten of Cadet; and the solution may be substituted for the solution in alcohol as a varnish; but it does not answer to mix it with colours\*.

Concentrated sulphuric acid renders it violet coloured, and at last black; inflammable air escapes, and charcoal, water, and a portion of ammonia, are formed†. When nitric acid is poured on it, and heat applied, there is a quantity of azotic gas emitted, as Berthollet discovered; and by continuing the heat, some little oxalic acid is formed‡, and likewise malic acid, while a number of yellow-coloured oily flakes make their appearance in the solution.

Muriatic acid dissolves gluten with facility when its action is assisted by heat. When gluten is placed in oxymuriatic acid it softens, and seems to dissolve, but soon coagulates again into yellow-coloured flakes, which become transparent and greenish coloured by drying. When heated, they exhale oxymuriatic acid, and assume the appearance of common gluten§. This acid has the property of precipitating gluten from water in the state of yellowish white flakes.

6. Alkalies dissolve gluten when they are assisted

Alkalies,

\* Cadet, *Ann. de Chim.* xli. 316.

† Fourcroy, vii. 304.

‡ Vauquelin, *Ann. de Chim.* vi. 278.

§ Fourcroy and Vauquelin, *Ann. de Mus. d'Hist. Nat.* No. xxxvii. 2.

**Book IV.** by heat. The solution is never perfectly transparent. Acids precipitate the gluten from alkalies, but it is destitute of its elasticity \*. Alkalies, when much concentrated, form with it a kind of soap, converting it into oil and ammonia; which last is dissipated during the trituration.

**Nutgalls,** 7. Gluten is precipitated from water, and from some of its other solutions, by the infusion of nutgalls. The colour of the precipitate is usually yellowish brown, and it does not dissolve though the solution be heated.

8. The action of the metallic oxides and their salts upon gluten has not been tried.

It has a strong affinity for the colouring matter of vegetables, and likewise for resinous bodies.

**Heat.** 9. When moist gluten is suddenly dried, it swells amazingly. Dry gluten, when exposed to heat, cracks, swells, melts, blackens, exhales a fetid odour, and burns precisely like feathers or horn. When distilled, there come over water impregnated with ammonia and an empyreumatic oil; the charcoal which remains is with difficulty reduced to ashes.

10. The properties of this substance clearly point out a resemblance between it and animal matter; and the phenomena of its fermentation and destructive distillation show us that oxygen, hydrogen, carbon, and azote, are constituents of it. Proust first observed that the vapour which it emits, while fermenting, blackens silver and lead, and of course contains sulphur.

11. Like all other vegetable principles, gluten is susceptible of various shades of properties, which consti-

---

\* Fourcroy.



tain so many species. In wheat flour it occurs in the greatest abundance, and from it we can extract it with the greatest ease: But the sagacity and industry of Ronelle and Proust have detected its presence in many other vegetable substances. Ronelle found it in the leaves of all the vegetable substances which he examined. The exactness of this opinion was called in question by Fourcroy, who treated the experiments of Ronelle with contempt; but it has been lately examined, and confirmed by very decisive experiments of Proust.

When the juice of cabbage leaves, cresses, scurvy-grass, and other similar plants, is extracted by pressure and passed through a cloth, it still continues far from transparent. Its muddiness is owing to a fine soft silky green powder suspended in it, which subsides to the bottom so slowly as to take at least a week before it is deposited. This green powder has been distinguished by the name of the *green fecula* of plants. Ronelle first examined it with attention, and ascertained its properties; and the subject has been carried still farther by Proust. The slowness with which it subsides, shows that its specific gravity does not differ much from that of water. When once it has fallen, it is insoluble. This substance consists chiefly of three principles: 1. A green matter to which it owes its colour, separated by digestion in alcohol, and which possesses the properties of a resin. 2. A substance which consists chiefly of woody fibres, and which is left behind when the fecula is digested in potash. 3. A species of gluten, which constitutes the greatest part of it, and to which it owes its characteristic properties.

Green fecula contain gluten.

Book IV.

When the juice of the plants is exposed to a heat of about  $130^{\circ}$ , the green fecula undergoes a kind of coagulation, concreting into large flakes, which subside very quickly. At this temperature albumen is not altered by heat. This is the method commonly taken to *clarify* these juices. We see from it, that the fecula was united to the water by a very small force, which the addition of heat weakened sufficiently to enable the gluten to cohere. This coagulation by heat takes place how diluted soever the juices are with water; which is by no means the case with albumen. It is thrown down also by the addition of a little Alcohol, by all acids, by ammonia, by sulphureted hydrogen gas, or by throwing into the liquid crystals of carbonate of potash, magnesia, common salt, muriate of potash, nitre, sal ammoniac, &c.

When separated from water it soon dries, and becomes elastic, and somewhat of the appearance of horn; and in that state is scarcely softened by hot water. When treated like gluten, it gradually acquires the cheesy taste and smell. When kept under water it very soon begins to putrefy, and exhales a gas which blackens silver and solutions of lead. This speedy putrefaction in stagnant water takes place when flax and hemp are steeped. These substances contain green fecula in their rind, and the putrefaction occasions the separation of the whole, which could not otherwise be accomplished. The water which has been allowed to remain for a whole year over green fecula contains sulphureted hydrogen, carbonate of ammonia, and gluten seemingly held in solution by the ammonia. The

stench of putrefaction still continues even after the water has been boiled \*.

Chap. I.

12. The number of plants containing gluten is very considerable. Proust found it in acorns, chesnuts, horse-chesnut, rue, barley, rye, peas, and beans; and in apples and quinces. He found it also in the leaves of cabbage, sedums, cress, hemlock, borage, saffron, &c.; in the berries of the elder, the grape, &c.; in the petals of the rose, &c. †. It occurs also in several roots: Proust could find none in the potato.

Plants containing gluten.

13. Gluten must be considered as one of the most useful of the vegetable principles. It constitutes an essential ingredient in wheat, and is the substance which renders flour of wheat so fit for forming bread. It seems also to constitute the essential part of yeast. Its uses as a varnish, a ground for paint, &c. pointed out by Cadet, likewise deserve attention.

### SECT. XIII.

#### OF ALBUMEN.

ALBUMEN is the term by which chemists have agreed to denote the *white of egg*, and all glary tasteless substances which, like it, have the property of coagulating into a white, opaque, tough, solid substance, when

\* Proust, *Jour. de Phys.* lvi. 97.

† Id. *Ibid.*

Book IV.  
History.

heated a little under the boiling point. This substance forms a constituent of many of the fluids of animal bodies ; and when coagulated, it constitutes also an important part of their solids. Substances analogous to it had been noticed by chemists in the vegetable kingdom. Scheele affirmed, as early as 1780, that the greater number of plants contained a substance analogous to curd \*. Fourcroy, about the year 1790, announced the existence of albumen in a variety of plants † ; but Proust has since shown, that the substance which he took for albumen, and which had been already examined by Rouelle, was not possessed of the properties which characterise that animal matter ‡. But Vauquelin has lately discovered albumen in abundance in the juice of the papaw tree ; so that its existence as a vegetable principle cannot be disputed.

Found in  
papaw  
juice.

The *papaw tree*, the *carica papaya* of botanists, grows in Peru, &c. and in the Isle of France, where the milky juice that exudes from it is said to be employed with efficacy against the *Guinea worm*. Two specimens of this juice were brought from that island to Paris by Charpentier de Cossigny. In the one, the juice had been evaporated to dryness, and was in the state of an extract ; in the other, the juice was preserved by being mixed with an equal bulk of rum. Both were subjected to a chemical analysis by Vauquelin. The first was of a yellowish white colour, and semitransparent. Its taste was sweetish. It had no smell, and was pretty solid ; but attracted moisture

\* Scheele, ii. 55.

† *Ann. de Chim.* iii. 259.

‡ *Jour. de Phys.* lvi. 97



when kept in a damp place. The second was reddish brown, and had the smell and taste of boiled beef. When the first specimen was macerated in cold water, the greatest part of it dissolved. The solution frothed with soap. The addition of nitric acid coagulated it, and rendered it white; and when boiled, it threw down abundance of white flakes. These flakes were coagulated albumen\*.

Other specimens of this juice, both in the liquid and dried state, have been examined more recently by Vauquelin†, and likewise by Cadet‡.

The essential characters of albumen are the following: Properties.

1. In its natural state it is soluble in water, and forms a glary limpid liquid, having very little taste; which may be employed as a paste, and which forms a very shining varnish.
2. The solution is coagulated by acids, pretty much in the same way as milk is coagulated by the same reagents.
3. When not too much diluted, it is coagulated also when heated to the temperature of  $176^{\circ}$ .
4. Albumen dissolved in water is precipitated in the state of brown flakes by the infusion of tan.
5. The solution is equally coagulated when mixed with alcohol.
6. Albumen is precipitated from water in the state of white powder by the salts of most of the white metals; such as silver, mercury, lead, tin, &c.

\* *Ann. de Chim.* xliii. 267.

† *Ibid.* xlix. 295.

‡ *Ibid.* xlix. 250, and l. 319.

Book IV.

The juice of the papaw possessed all these properties \*. It therefore contained albumen. In few other vegetable productions has this substance been yet found in such abundance, or in a state in which its properties were so decidedly characteristic; but the resemblance between the curd of milk and albumen is very close, as we shall see afterwards. Now Proust has ascertained that *almonds*, and other similar kernels from which *emulsions* are made, contain a substance which has the properties of curd †.

Albumen when burnt emits ammonia; and when treated with nitric acid, yields azotic gas. It evidently, then, contains azote. But as it is more properly an animal than a vegetable substance, I shall defer giving any farther account of its properties till I come to treat of animal bodies.

And in other plants.

The papaw is not the only plant which contains this vegetable albumen in abundance. The juice of the fruit or pods of the *bibiscus esculentus* contains it also in such quantity that it may be employed, as I am informed by Dr Clarke of Dominica, as a substitute for whites of eggs in clarifying the syrup of the sugar cane. By the same gentleman I have been informed of a curious property which the green juice of the papaw possesses. Meat (even salt meat), when well rubbed with it, becomes in about an hour quite tender. People are not fond of eating meat which has been made tender by this means, though Dr Clarke assures me he has eaten it without any bad effect whatever.

---

\* Vauquelin, *Ann. de Chim.* xliii. 267.

† *Jour. de Phys.* lxi. 88.

Fourcroy and Vauquelin have lately found, in the pollen of the *phœnix dactylifera* or date tree, a substance which possesses properties analogous to *albumen*. By Vauquelin, in his recent analyses, it is usually designated *vegeto-animal principle*.

Chap. I.  
Found in the pollen of the *phœnix dactylifera*.

When the pollen of this tree was digested in cold water, and the liquid evaporated, a brown substance remained. A portion of this extract dissolved in alcohol; another portion in water; and a third remained insoluble in both. The portion soluble in water, when mixed with ammonia, let fall a quantity of *phosphate of magnesia*. The solution, concentrated by evaporation, formed crystals of malate of ammonia. After the separation of these a substance still remained, which formed a copious precipitate with infusion of nutgalls, and possessed other properties similar to *albumen* \*.

---

## SECT. XIV.

### OF FIBRIN.

THAT peculiar substance which constitutes the fibrous part of the muscles of animals has been called *fibrin* by chemists. A substance resembling it, as it exists in the

---

\* Fourcroy and Vauquelin, *Annales de Museum d'Histoire Naturelle*, t. 437.

**Book IV.**

blood; has been detected by Vauquelin in the juice of the papaw tree; the same juice which contained albumen in such plenty. Fibrin then must be ranked among vegetable substances.

**Found in the papaw.**

When the juice of the papaw is treated with water the greatest part dissolves; but there remains a substance insoluble, which has a greasy appearance. It softens in the air, and becomes viscid, brown, and semitransparent. When thrown on burning coals melted, let drops of grease exude, emitted the noise of meat roasting, and produced a smoke which had the odour of fat volatilized. It left behind it no residue. This substance was the *fibrin*. The resemblance between the juice of the papaw and animal matter is so close, that one would be tempted to suspect some composition, were not the evidence that it is really the juice of a tree quite unexceptionable\*.

The properties of fibrin are the following:

**Properties.**

1. It is tasteless, fibrous, elastic, and resembles gelatin.
2. It is insoluble in water and in alcohol.
3. It is not dissolved by diluted alkalies.
4. But acids dissolve it without difficulty.
5. With nitric acid it gives out much azotic gas.
6. When distilled it yields much carbonate of ammonia and oil.
7. It soon putrefies when kept moist, becomes green but does not acquire any resemblance to cheese.

A fuller description of this substance must be reserved for the next Book, as it belongs rather to the animal than vegetable kingdom.

---

\* *Ann. de Chim.* xliiii. 267.



## SECT. XV.

## OF THE BITTER PRINCIPLE.

MANY vegetable substances have an intensely bitter taste, and on that account are employed in medicine; by brewers, &c. This is the case with the wood of the *quassia amara* and *excelsa*, the common *quassia* of the shops; with the roots of the *gentiana lutea*, common *gentian*; the leaves of the *humulus lupulus* or *hop*; the bark and wood of the *spartium scoparium* or common broom; the flowers and leaves of the *antibemis nobilis* or *chamomile*; and many other substances. Some of these bodies owe their bitter taste to the presence of a peculiar vegetable substance differing from every other, which may be distinguished by the name of the *bitter principle*.

Plants containing bitter principle.

No chemical examination of this substance has been hitherto published; nor indeed are we in possession of any method of separating it from other bodies, or of ascertaining its presence. At the same time it cannot be doubted that it possesses peculiar characters; and its action on the animal economy renders it an object of importance.

1. When water is digested over *quassia* for some time, it acquires an intensely bitter taste and a yellow colour, but no smell. When water thus impregnated is evaporated to dryness in a low heat, it leaves a brown-

Experiments on the infusion of quassia.

Book IV. ish-yellow substance, which retains a certain degree of transparency. It continues ductile for some time, but at last becomes brittle. This substance I shall consider as the bitter principle in a state of purity. If it contain any foreign body, it must be in a very minute proportion. This substance I find to possess the following properties.

1. Its taste is intensely bitter. Colour brownish yellow.

2. When heated, softens, and swells, and blackens then burns away without flaming much, and leaves a small quantity of ashes.

3. Very soluble in water and alcohol.

4. Does not alter the colour of infusion of litmus.

5. Lime-water, barytes-water, and strontian-water occasion no precipitate. Neither is any precipitate thrown down by silicated potash, aluminated potash, or sulphate of magnesia.

6. The alkalis occasion no change in the diluted solution of the bitter principle.

7. Oxalate of ammonia occasions no precipitate.

8. Nitrate of silver renders the solution muddy, and a very soft flaky yellow precipitate falls slowly to the bottom.

9. Neither corrosive sublimate nor nitrate of mercury occasion any precipitate.

10. Nitrate of copper, and the ammoniacal solution of copper, produce no change; but muriate of copper gives the white precipitate, which falls when this liquid salt is dropped into water.

11. Sulphate and oxymuriate of iron occasion no change.

12. Muriate of tin renders the solution muddy, but

occasions no precipitate, unless the solution be concentrated; in that case a copious precipitate falls.

13. Acetate of lead occasions a very copious white precipitate; but the nitrate of lead produces no change.

14. Muriate of zinc occasions no change.

15. Nitrate of bismuth produces no change, though when the salt is dropt into pure water a copious white precipitate appears.

16. Tartar emetic produces no change; but when the muriate of antimony is used, the white precipitate appears, which always falls when this salt is dropt into pure water.

17. Muriate and arseniate of cobalt occasion no change.

18. Arseniate of potash produces no effect.

19. Tincture of nutgalls, infusion of nutgalls, galli acid, occasion no effect.

These properties are sufficient to convince us that the bitter principle is a substance differing considerably from all the other vegetable principles. The little effect of the different reagents is remarkable. Nitrate of silver and acetate of lead are the only two bodies which throw it down. This precipitation cannot be ascribed to the presence of muriatic acid; for if muriatic acid were present, nitrate of lead would also be thrown down. Besides, the flakes produced by nitrate of silver are too light, and indeed have no resemblance whatever to muriate of silver. The precipitate by acetate of lead is very copious. This salt is therefore the best substance for detecting the presence of the bitter principle, when we are certain that no other substance is present which throws down lead.

## Book IV.

Exists in  
other  
plants.

Vauquelin has lately examined the bitter principle in the fruit of the colocynth (*cucumis colocynthis*), in the root of the briony (*brionia alba*), two vegetable bodies which have been employed in medicine, possess strong lethargic powers. The bitter principle in these substances, as far as his experiments were, possess exactly the properties of the bitter principle of quassia \*. It is probable also that hops, gentian, broom, contain the same bitter principle.

When alcohol is digested for some months with wheat flour, and then distilled, it leaves a yellow brown substance behind it, which possesses (as far as have examined it) all the properties of the bitter principle of quassia.

Second species of bitter principle.

II. Besides this purest species of bitter principle it is probable that several others exist in the vegetable kingdom, gradually approaching by their qualities to the nature of *artificial tannin*. The second species is distinguished from the preceding, by the property which it has of striking a green colour with iron, and of precipitating that metal from concentrated solutions. Chenevix separated a portion of it from coffee by the following process: He digested unburnt coffee in water and filtered the liquid. It was then treated with muriatic acid of tin. The precipitate wasedulcorated, mixed with water, and treated with sulphureted hydrogen. The tin was thus precipitated, and the substance which it had been combined was dissolved by the aqua regia. The liquid was then evaporated to dryness.

---

\* Vauquelin, *Essai's Analytiques des Racines d'Ellébore d'Hiver et de Printemps*. *Ann. de Mus. d'Hist. Nat.* No. xliii. 91.

substance thus obtained possessed the following properties :

1. Semitransparent like horn, and of a yellow colour,
2. When exposed to the air, it does not attract moisture.
3. Soluble in water and in alcohol. The solution in water is semitransparent, and has a pleasant bitter taste. When the alkaline solutions are dropt into it, the colour becomes garnet red.
4. It is not precipitated from water by the alkaline carbonates. Sulphuric acid renders the solution brown, but produces no further change. Neither muriatic acid, nor phosphoric acid, nor the vegetable acids, produce any change on this solution.
5. The muriates of gold, platinum, and copper, occasion no change.
6. With solutions of iron it forms a fine green coloured liquid ; and when concentrated, iron throws down a green coloured precipitate. Indeed it is almost as delicate a test of iron as tan and gallic acid.
7. Muriate of tin throws down a copious yellow precipitate. This precipitate, and that by iron, are soluble in all acids, but they lose their colour.
8. Neither lime nor strontian water occasion any precipitate in the aqueous solutions of this substance ; but barytes water occasions a brown precipitate.
9. Gelatine occasions no precipitate \*.

From the experiments of Bouillon la Grange, it appears that a substance similar to this second species of bitter principle exists in the flowers of the *arnica mon-*

---

\* *Phil. Mag.* 1802, May, p. 350.



Book IV.

*tana* \*. There is reason for believing that the bitter principle which characterizes the following plants belongs also to this second species; *absinthium vulgare* (worm-wood), *juniperus sabinus* (sabine), *ruta graveolens* (rue), *anthemis nobilis* (chamomile), *achillea millefolium* (milfoil).

Third species.

III. The Third species may be distinguished by the name of *artificial bitter principle*, as it has been formed by the action of nitric acid on various vegetable and animal substances. It was first obtained by Hausman while examining indigo, but he mistook its nature. Welther afterwards formed it by digesting silk in nitric acid, ascertained its properties, and gave it the name of *yellow bitter principle* †; he is therefore to be considered as the real discoverer. Bartholdi afterwards procured it by treating the *white* willow with nitric acid ‡. Mr Hatchett lately obtained it during his experiments on artificial tannin, by treating indigo with nitric acid §; and about the same time Fourcroy and Vauquelin procured it by the same means, and examined its properties in detail ||. This substance possesses the following properties ¶.

Its colour is a deep yellow, its taste intensely bitter. It is soluble both in water and alcohol, and has the property of dyeing silk, woollen cloth, and cotton, of a durable yellow colour. It crystallizes in elongated plates, and possesses many of the characters of an acid, combining readily with alkaline substances, and form-

\* *Ann. de Chim.* lv. 35.    † *Ibid.* xlii. 301.    ‡ *Ibid.* xxiii. 187

§ *Phil. Trans.* 1801.    || *Phil. Mag.* xviii. 255.

¶ See the method of procuring it described in Section N.

ing crystallizable salts. When potash is dropt into a concentrated solution of it, small yellow prismatic crystals are gradually deposited, consisting of bitter principle combined with potash. These crystals were examined by Welther, but it was Fourcroy and Vauquelin that ascertained their composition. They have a bitter taste, are not altered by exposure to the air, are less soluble than pure bitter principle. When thrown upon hot charcoal they burn like gunpowder, and detonate very loudly when struck upon an anvil, emitting a purple light \*. Ammonia dropt into the solution of bitter principle deepens its colour, and occasions a copious deposition of fine yellow spicular crystals. These are a combination of bitter principle and ammonia †.

IV. Artificial tannin itself may be considered as approaching the bittter principle in many of its properties. Its taste is always intensely bitter, and the colour of the precipitates which it throws down from the metals, is similar to what takes place when artificial bitter principle is present. It is indeed possible, that the bitter taste may be owing not to the tannin, but to a portion of artificial bitter principle which may be always formed along with the tannin; but this has not been ascertained. It is well known that the bitter taste very easily overpowers and conceals all other tastes.

Fourth species.

\* Welther, Fourcroy, and Vauquelin.

† Hatchett, *Phil. Trans.* 1805.

## SECT. XVI.

## OF TANNIN.

NOTWITHSTANDING the numerous experiments made upon the intusion of nutgalls, we are not in possession of a process capable of furnishing tannin in a state of purity. Hence the obscurity which still hangs over its characters. The properties of this substance, as far as known, and the different methods of procuring it hitherto proposed by chemists, have been detailed in a preceding part of this Work. In that account the labours of Bouillon la Grange \*, who has added considerably to the number of facts collected by his predecessors, and modified in some particulars, the received opinions, have been omitted. His process for procuring pure tannin is as follows: Into an infusion of nutgalls, made with cold water, drop a solution of crystallized carbonate of ammonia, as long as any precipitate continues to fall. Separate the precipitate by a filter, and wash it with cold water till the liquid comes off colourless. Then digest it repeatedly in alcohol, of the specific gravity 0.817, till the liquid ceases to redden the tincture of litmus. Dry it between folds of blotting

New method of obtaining tannin.

---

\* *Ann. de Chim.* lvi. 272.



paper. Such is the process; but no reason is assigned for considering the tannin thus procured as pure.

Chap. I.

The tannin of this process is white, has a bitter taste, and reddens litmus paper. It does not melt when heated, nor does it alter, if dry, by exposure to the air. It dissolves sparingly in cold, but readily in hot water. By the action of oxymuriatic acid, it seems to be converted into gallic acid. Hence it is probable that gallic acid and tannin differ merely in the proportion of oxygen which they contain. Lime, barytes, and strontian water precipitate tannin green. The fixed alkalis deepen the colour, and prevent the tannin from acting on gelatine. It deprives several of the metallic oxides either of the whole, or of a portion, of their oxygen. When red oxide of iron is boiled in the solution of tannin, it becomes blackish brown, and combines to saturation with tannin. In like manner red oxide of lead deprives the solution of the whole of its tannin, and assumes a dark brown colour. Red oxide of mercury assumes the same colour, and produces the same effect.

Its properties.

With acetate of lead it forms a dark grey heavy precipitate, and the whole of the lead is abstracted from the solution. The precipitate, when first dried, is greenish, but becomes brown by exposure to the air. Copper is thrown down brown from its solutions. The precipitation is incomplete. Sulphate of manganese is thrown down green, but the precipitate becomes brown by exposure to heat. Nitrate of mercury is precipitated yellow. When the tannate of iron is dissolved in muriatic acid, barytes occasions no precipitate; a proof that it contains no sulphuric acid. These are the most important of the facts noticed by Bouillon la Grange in his Dissertation on Tannin.

## Book IV.

Tannin exists in a great variety of substances. The bark of many trees contain it abundantly. It is found also in the roots, wood, and branches of many. Sometimes it is accompanied by gallic acid, and sometimes not. The presence of this acid may be distinguished by the action of the infusion on the salts of iron. When the precipitate subsides quickly, it is a proof that gallic acid is present; but if it subsides very slowly, may conclude that this acid is present\*.

## Species of tannin.

Like most other vegetable substances, it seems to be susceptible of different modifications. The following are the different species of tannin which have hitherto noticed,

## From nutgalls.

1. Tannin from nutgalls. This is the common species described in this Work under the name of tannin. It precipitates iron black, and forms a firm insoluble brown precipitate with glue. The bark of oak, most other astringent trees in this country, are supposed to contain this species of tannin,

## Catechu.

2. The tannin which constitutes so large a proportion of catechu forms the second species. Its peculiar nature was first observed by Proust. It was afterwards more particularly examined by Mr Davy. It forms with iron an olive coloured precipitate.

## Kino.

3. The tannin of *kino* constitutes a third species. This substance is obtained from different vegetables. It was originally imported, as is supposed, from Africa; but at present the common kino of the shops is, according to Dr Duncan, an extract from the *coccoloba uvifera*, or *sea-side grape*, and is brought chiefly from

---

\* Berthollet, sur la Tannin, i. 108.

Jamaica. But the finest kino is the product of different species of *eucalyptus*, particularly the *resinifera* or brown gum tree of Botany Bay \*. It is an astringent substance of a dark red colour, and very brittle. It dissolves better in alcohol than water. The solution in the latter liquid is muddy; in the former transparent, and a fine crimson if sufficiently diluted. It throws down gelatine of a rose colour, and forms with salts of iron a deep green precipitate, not altered by exposure to the air. These properties, first observed by Dr Duncan, and afterwards by Vauquelin, show that it contains abundance of tan, but in a particular state †.

4. The fourth variety of tannin is contained in *su-* Sumach,  
*carb.* This is a powder obtained by drying and grinding the shoots of the *rhus coriaria*; a shrub cultivated in the southern parts of Europe. The tan, which it contains in abundance, yields a precipitate with gelatine, which subsides very slowly, and remains in the state of a white magma without consistence.

5. The fifth variety, according to Proust, is to be *Fustic.*  
found in the wood of the *morus tinctoria*, or *old fustic* as the British dyers term it. This wood gives out an extract both to alcohol and water, which yields a precipitate with gelatine. A solution of common salt is sufficient to throw it down ‡.

Tannin affects particularly the bark of trees; but it exists also in the sap and in the wood of a considerable number, and even in the leaves of many. It is very seldom that it exudes spontaneously; yet this seems to

\* Nicholson's Jour. vi. 234.

† Ann. de Chim. xlvii. 327.

‡ Proust, Ann. de Chim. xlii. 94.

**Book IV.** be the case with a variety of kino from Botany Bay which I have lately examined.

It has been ascertained by Mr Biggin\*, that when the barks of trees are examined at different seasons they vary in the quantity of tan. The quantity varies with the age and size of the trees†. The greatest portion of tan is contained in the inner bark‡. The epidermis usually contains none.

The following Table exhibits the proportion of solid matter extracted by water from different vegetable substances, and the quantity of tan contained in that solid matter, as ascertained by the experiments of Mr Davy

Table of  
the quan-  
tity of tan-  
nin in  
plants.

One ounce of	Solid Matter. Grains.	T Gr
White inner bark of old oak.....	108	...
.....young oak.....	111	...
.....Spanish chesnut....	89	...
.....Leicester willow....	117	...
Coloured or middle bark of oak.....	43	...
.....Spanish chesnut	41	...
.....Leicester willow	34	...
Entire bark of oak.....	61	...
.....Spanish chesnut.....	53	...
.....Leicester willow.....	71	...
.....elm.....	—	...
.....common willow.....	—	...
Sicilian sumach .....	165	...
Malaga sumach .....	156	...
Souchong tea .....	—	...
Green tea.....	—	...

\* *Phil. Trans.* 1798, p. 299.

† *Davy, Ibid.* 1803.

‡ *Davy, lb*

One ounce of	Chap. I.	
	Solid Matter. Grains.	Tan. Grains.
Bombay catechu.....	—	... 261
Bengal catechu .....	—	... 231
Nutgalls.....	180	... 127

## SECT. XVII.

## OF THE EXTRACTIVE PRINCIPLE.

THE word *extract* was at first applied to all those sub-<sup>History.</sup>stances which were extracted from plants by means of water, and which remained behind in the state of a dry mass when the water was evaporated ; consequently it included gum, jelly, and several other bodies. But of late it has been confined by many to a substance which exists in many plants, and which may be obtained nearly in a state of purity, according to Hermbstadt, by infusing *saffron* in water for some time, filtrating the infusion, and evaporating it to dryness. But as the word *extract* occurs even in modern authors in its original sense, I shall rather denote this substance by the phrase *extractive principle*, to prevent ambiguity.

The difficulty of obtaining the extractive principle in a separate state, and the facility with which it alters its nature, have hitherto prevented chemists from examining it with that attention to which it is entitled. It was first particularly attended to by Rouelle ; but it is to Fourcroy and Vauquelin that we are chiefly indebted.



**Book IV.** ed for ascertaining its characters. The dissertation of Vauquelin in the *Journal de Pharmacie*, is by far the best account of extractive matter which has hitherto appeared. Many valuable facts and curious observations were published by Hermstadt also in his dissertation on *extract* \*. But unfortunately the term has not been always taken by chemists in the same acceptation. Parmentier has lately published a dissertation on the *extracts* of vegetables taken in the loose and general sense of the word, which contains much information †.

The extractive principle possesses the following properties:

**Properties.**

1. Soluble in water, and the solution is always coloured. When the water is slowly evaporated, the extractive matter is obtained in a solid state and transparent; but when the evaporation is rapid the matter is opaque.
2. The taste of extractive is always strong; but it is very different according to the plant from which it is obtained.
3. Soluble in alcohol, but insoluble in ether.
4. By repeated solutions and evaporations, the extractive matter acquires a deeper colour, and becomes insoluble in water. This change is considered as the consequence of the absorption of the oxygen of the atmosphere, for which the extractive principle has a strong affinity. But if the solution be left to itself, exposed to the atmosphere, the extract is totally destroyed in consequence of a kind of putrefaction which speedily commences.

---

\* See his *Physical Chemistry*, ii. 65. See also Crell's *Annals*, 1798. ii. 433.

† *Ann. de Chim.* xliii. 19

5. When oxymuriatic acid is poured into a solution containing extractive, a very copious dark yellow precipitate is thrown down, and the liquid retains but a light lemon colour. These flakes are the oxygenized *extractive*. It is now insoluble in water; but hot alcohol still dissolves it.

6. The extractive principle unites with alumina, and forms with it an insoluble compound. Accordingly, if sulphate or muriate of alumina be mixed with a solution of extractive, a flaky insoluble precipitate appears, at least when the liquid is boiled; but if an excess of acid be present, the precipitate does not always appear.

7. It is precipitated from water by concentrated sulphuric acid, muriatic acid, and probably by several other acids. When the experiment is made with sulphuric acid, the fumes of vinegar generally become visible.

8. Alkalies readily unite with extractive, and form compounds which are insoluble in water.

9. The greater number of metallic oxides form insoluble compounds with extractive. Hence many of them, when thrown into its solution, are capable of separating it from water. Hence also the metallic salts mostly precipitate extractive. Muriate of tin possesses this property in an eminent degree. It throws down a brown powder perfectly insoluble, composed of the oxide of tin and vegetable matter.

10. If wool, cotton, or thread, be impregnated with alum, and then plunged into a solution of extractive, they are dyed of a fawn brown colour, and the liquid loses much of its extractive matter. This colour is permanent. The same effect is produced if muriate of tin be employed instead of alum. This effect is still more



**Book IV.** complete if the cloth be soaked in oxymuriatic acid, and then dipt into the infusion of extractive. Hence we see that the extractive matter requires no other mordant than oxygen to fix it on cloth.

11. When distilled, extractive yields an acid liquid impregnated with ammonia\*.

**Properties  
of extracts.**

It cannot be doubted that there are many different species of extractive matter; though the difficulty of obtaining each separately has prevented chemists from ascertaining its nature with precision. Extracts are usually obtained by treating the vegetable substance from which they are to be procured with water, and then evaporating the watery solution slowly to dryness. All extracts obtained by this method have an acid taste, and redden the infusion of litmus. They all yield a precipitate while liquid if they are mixed with ammonia. This precipitate is a compound of lime and insoluble extractive. Lime always causes them to exhale the odour of ammonia. It has been ascertained that the extractive principle is more abundant in plants that have grown to maturity than in young plants.

As the *extracts* of vegetables prepared by apothecaries for medical purposes, besides the extractive principle, always contain other bodies, frequently to the number of eight or more, and as the greater number of them are still but imperfectly examined, I shall satisfy myself at present with pointing out some of those vegetable substances which have been ascertained to contain extractive principle, and stating the constituents of such as have been analysed.

---

\* See Vauquelin.

1. Extractive principle is not an uncommon ingredient in the sap of trees. Indeed Deyeux and Vauquelin found it in almost all those which they examined. It is usually thrown down when the sap is mixed with oxymuriatic acid, and it precipitates in brown flakes while the sap is evaporating on a sand bath.

Chap. I.  
Extractive  
of sap.

2. It forms a constituent of the bark of all trees hitherto examined. This was evidently the case with all the barks which Mr Davy subjected to experiment; namely, those of oak, Leicester willow, Spanish chestnut, elm, common willow, and undoubtedly all barks which have an astringent taste; for tan and extractive seem scarcely ever to be found separate.

Of bark.

3. The infusion of catechu contains an extractive principle, united chiefly to tan. It may be obtained in a state of purity by washing the catechu in powder repeatedly with water till the fluids obtained cease to precipitate gelatine. What remains is extractive. It is of a pale reddish brown colour and a slightly astringent taste, leaving in the mouth a sensation of sweetness. It has no smell. Its solution in water is at first yellow brown; but it acquires a tint of red when left exposed to the air. The solution in alcohol is of a dirty brown. It does not affect vegetable blues. Alkalies brighten its colour; but, neither these bodies nor the alkaline earths precipitate it from water. Nitrate of alumina and muriate of tin render the solution slightly turbid. Nitrate of lead throws down a dense light-brown precipitate. It renders oxysulphate of iron green, and throws down a green precipitate, becoming black by exposure to the air. Linen, when boiled in the solution, extracts almost the whole of the extractive, and acquires a light red brown colour. When this extra-

Of catechu.

Book IV.

tive is exposed to heat, it softens, and its colour becomes darker, but it does not melt. When distilled, it yields carbonic acid and carbureted hydrogen gas, weak acetic acid, and a little unaltered extractive. A porous charcoal remains \*.

Of senna,

4. The infusion of senna contains a matter of a very peculiar nature, but which may be considered as a species of *extractive*. The senna of commerce consists of the dried leaves of the *cassia senna*, a shrub-like annual cultivated in Egypt. Water, at the ordinary temperature of the atmosphere, dissolves nearly one-half of the substance of these leaves. The infusion obtained has a brown colour, a bitter taste, and a peculiar aromatic odour. It contains a considerable proportion of carbonate of lime, sulphate of potash, and carbonate of magnesia, besides a little silica; but the most curious of its constituents is the extractive. When common air is made to pass for some hours through the infusion, a yellow coloured precipitate appears: the same substance is thrown down immediately by muriatic acid and oxy-muriatic acid. It appears also when a current of oxygen gas is made to traverse the infusion. This substance is the extractive altered by its combination with oxygen. It has a slight bitter taste. It is no longer soluble in water. Alcohol dissolves it, but lets it fall when diluted. The alkalies dissolve it, and form a deep brown solution. On burning coals it emits a thick smoke, exhales an aromatic odour, and leaves a spongy charcoal. These properties indicate a very decided approach to the resinous state †.

\* Davy on *Astringent Vegetables*, p. 25.

† Bouillon La Grange, *Ann. de Chim.* xiv. 4.

5. The infusion of Peruvian bark likewise yields an extractive matter of a peculiar nature, which assumes a fine red colour when united to oxygen; and, like the extractive of senna, acquires nearly the properties of a resin. It was obtained by Fourcroy from the quinquina of St Domingo. Water, boiled on it till it refused to dissolve any thing more, was slowly evaporated, and the extract obtained was dissolved in alcohol. The alcohol, by evaporation, deposited the peculiar extractive. Its colour was brown, its taste bitter, insoluble in cold, but very soluble in hot water. It was soluble in alcohol. When dry it was black, brittle, and broke with a polished fracture. Lime-water precipitated it in the state of a red powder: oxymuriatic acid threw it down in the state of a fine red powder, neither soluble in water nor alcohol, but capable of uniting with alkalies. A stronger dose of oxymuriatic acid renders it yellow\*.

Chap. 2.  
Of quinquina.

6. Saffron yields extractive matter in great abundance. This substance consists of the summits of the pistils of the *crocus sativus*. Almost the whole of it is soluble in water.

Of saffron.

7. Steinacher has shown that distilled vinegar contains a quantity of extractive†.

The resemblance between extractive bodies and the colouring matter of plants is sufficiently striking. It is more than probable, that when this last set of bodies have been examined with more precision by chemists, they will be found to belong to the same class.

\* Fourcroy, *Ann. de Chim.* viii. 120.

† *Jour. de Phys.* lxx. 327.



## SECT. XVIII.

## OF THE NARCOTIC PRINCIPLE.

IT has been long known that the milky juices which exude from certain plants, as the poppy, lettuce, &c. and the infusions of others, as of the leaves of the *digitalis purpurea*, have the property of exciting sleep, or, if taken in large enough dozes, of inducing a state resembling apoplexy, and terminating in death. How far these plants owe these properties to certain common principles which they possess is not known; though it is exceedingly probable that they do. But as a *peculiar substance* has been detected in *opium*, the most noted of the narcotic preparations, which possesses narcotic properties in perfection, we are warranted, till further experiments elucidate the subject, to consider it as the *narcotic principle*, or at least as one species of the substances belonging to this genus.

Opium.

Opium is obtained from the *papaver album*, or white poppy, a plant which is cultivated in great abundance in India and the East. The poppies are planted in a fertile soil and well watered. After the flowering is over, and the seed capsules have attained nearly their full size, a longitudinal incision is made in them about sun-set for three or four evenings in succession. From these incisions there flows a milky juice, which soon concretes, and is scraped off the plant and wrought into cakes. In this state it is brought to Europe.

Its properties.

Opium thus prepared is a tough brown substance has a peculiar smell, and a nauseous bitter acrid

It becomes softer when held in the warm hand, and burns very readily and strongly. It is a very compound substance, containing sulphate of lime, sulphate of potash, an oil, a resinous body, an extractive matter, gluten, mucilage, &c. besides the peculiar narcotic principle, to which probably it owes its virtues as a narcotic. Almost all the medical chemists have published analyses of opium. To their labours indeed we are indebted for every thing concerning it at present known. Neumann, Hoffman, Trulles, Baumé, have distinguished themselves most; and more lately remarks have been published on it by Josse, Bucholz, Proust, and Déroanne. The dissertation of the last is peculiarly valuable. He first pointed out the nature and properties of the *narcotic principle* of opium. It had indeed been noticed by most of the older chemists, though they had formed erroneous opinions respecting its nature.

Chap. I.  
Constitu-  
ents.

When water is digested upon opium, a considerable portion of it is dissolved, the water taking up several of its constituents. When this solution is evaporated to the consistence of a syrup, a gritty precipitate begins to appear, which is considerably increased by diluting the liquid with water. It consists chiefly of three ingredients; namely, resin, oxygenized extractive, and the peculiar narcotic principle, which is crystallized. When alcohol is digested on this precipitate, the resin and narcotic substance are taken up, while the oxygenized extractive remains behind. The narcotic principle falls down in crystals as the solution cools, still however coloured with resin. But it may be obtained tolerably pure by repeated solutions and crystallizations \*.

Separation  
of the nar-  
cotic prin-  
ciple.

## Book IV.

Water is incapable of dissolving the whole of opium. What remains behind still contains a considerable portion of narcotic principle. When alcohol is digested on this residuum, it acquires a deep red colour; and deposits on cooling crystals of narcotic principle, coloured by resin, which may be purified by repeated crystallizations\*. The narcotic principle obtained by either of these methods possesses the following properties.

## Its properties.

1. Its colour is white. It crystallizes in rectangular prisms with rhomboidal bases. It has neither taste nor smell.

2. It is insoluble in cold water, soluble in about 400 parts of boiling water, but precipitates again as the solution cools. The solution in boiling water does not affect vegetable blues.

3. It is soluble in 24 parts of boiling alcohol and 100 parts of cold alcohol. When water is mixed with the solution, the narcotic principle precipitates in the state of a white powder.

4. Hot ether dissolves it, but lets it fall on cooling.

5. When heated in a spoon it melts like wax. When distilled it froths and emits white vapours, which condense into a yellow oil. Some water and carbonate of ammonia pass into the receiver; and at last carbonic acid gas, ammonia, and carbureted hydrogen gas, are disengaged. There remains a bulky coal, which yields traces of potash. The oil obtained by this process is viscid, and has a peculiar aromatic smell and an acrid taste.

6. It is very soluble in all acids. Alkalies throw it down from these solutions in the state of a white powder.

---

\* Derosne, *Ann. de Chim.* xlv. p. 271.



7. Alkalies render it rather more soluble in water. When they are saturated with acids, the narcotic principle falls down in the state of a white powder, which is redissolved by adding an excess of acid.

8. Volatile oils, while hot, dissolve it ; but, on cooling, they let it fall in an oleagenous state at first, but it gradually crystallizes.

9. When treated with nitric acid, it becomes red and dissolves ; much oxalic acid is formed, and a bitter substance remains behind.

10. When potash is added to the aqueous solution of opium, the narcotic principle is thrown down ; but it retains a portion of the potash.

11. Its solubility in water and alcohol, when immediately extracted from opium, seems to be owing to the presence of *resin* and *extractive matter*, both of which render it soluble.

12. It possesses the properties of opium in perfection. Derosne tried it upon several dogs, and found it more powerful than opium. Its bad effects were counteracted by causing the animals to swallow vinegar. This substance is known to be of equal service in counteracting the effects of opium. Derosne supposes that the efficacy of vinegar may be owing to the readiness with which it dissolves the narcotic principle \*.

Many other substances beside opium possess narcotic virtue ; but hitherto they have not been examined by chemists with much attention. The most remarkable are the following :

1. The *lactuca virosa*, and the *sativa* or garden let-

Narcotic  
plants.

---

\* Derosne, *Ann. de Chim.* p. 274.

Book IV.

tuce, and indeed all the *lactucas*, yield a milky juice, which, when inspissated, has very much the appearance of opium, and possesses the same properties. Indeed Dr Coxe of Philadelphia affirms, that as good opium may be obtained from the garden lettuce as from the poppy. The milky juice is obtained by incisions at the time when the lettuce is running to seed\*. The resemblance between the inspissated juice of the *lactuca virosa* and opium is striking.

2. The leaves of the *atropa belladonna*, or *deadly nightshade*, and indeed the whole plant, are remarkably narcotic; and when taken in too great doses produce blindness, convulsions, coma, and death.

3. The leaves of the *digitalis purpurea*, or *fox-glove*, are still more powerful if possible. They lower the pulse in a remarkable degree, and, like several other very poisonous narcotics, promote the discharge of urine.

4. *Hyosyamus niger* or hen-bane.

5. *Conium maculatum* or hemlock.

6. *Datura stramonium*.

7. *Ledum palustre*.

To these may perhaps be added the *prunus laurocerasus*, and the leaves of *nicotiana tabacum* or tobacco. The list indeed might be easily increased; almost all the plants belonging to the natural order of *luride* possessing narcotic properties: But as we are completely ignorant of the chemical properties of these plants, it is unnecessary to be more particular.

## SECT. XIX.

## OF OILS.

THERE are two species of oils ; namely, *fixed* and *volatile* ; both of which are found abundantly in plants.

1. *Fixed* oil is only found in the seeds of plants, and is almost entirely confined to those which have two cotyledons ; as linseed, almonds, beech root, poppy seed, rape seed, &c. Sometimes, though rarely, it is found in the pulp which surrounds the stone of certain fruits. This is the case with the olive, which yields the most abundant and most valuable species of fixed oil. The bicotyledinous seeds, besides oil, contain also a mucilaginous substance ; and they have all the character of forming, when bruised in water, a milky liquid, known by the name of *emulsion*.

The following is a list of the plants which yield the fixed oils which usually occur in commerce \*.

1. <i>Linum usitatissimum</i> et perenne	Linseed oil	List of fixed oils.
2. <i>Corylus avellana</i> }	Nut oil	
3. <i>Juglans regia</i> }		
4. <i>Papaver somniferum</i> .....	Poppy oil	
5. <i>Cannabis sativa</i> .....	Hemp oil	
6. <i>Sesamum orientale</i> .....	Oil of Sesamum	

\* See Gren's *Handb.* ii, 166.

## Book IV.

7. <i>Olea Europea</i> .....	Olive oi
8. <i>Amygdalus communis</i> .....	Almond
9. <i>Guilandina Mohringa</i> .....	Oil of b
10. <i>Cucurbita pepo et melapepo</i> .....	Cucum
11. <i>Fagus sylvatica</i> .....	Beech o
12. <i>Sinapis nigra et arvensis</i> .....	Oil of n
13. <i>Helianthus annuus et perennis</i> ...	Oil of su
14. <i>Brassica napus et campestris</i> .....	Rape se
15. <i>Ricinus communis</i> .....	Castor c
16. <i>Nicotiana tabacum et rustica</i> .....	Tabacco
17. <i>Prunus domestica</i> .....	Plum k
18. <i>Vitis vinifera</i> .....	Grape t
19. <i>Theobroma cacao</i> .....	Butter c
20. <i>Laurus nobilis</i> .....	Laurel
21. <i>Arachis hypogæa</i> .....	Ground

2. Volatile oils are found in every part of plant except the cotyledons of the seeds, where they never occur. The root, the stem, the leaves, the flower, the rind or pulp of the fruit of a variety of plants, are loaded with volatile oils, from which they are extracted by expression or by distillation. The number of plants is so great that it baffles all description. Almost every plant which is distinguished by a peculiar odour contains a volatile oil, to which it is indebted for its odour.

The following Table contains a pretty copious list of plants which yield volatile oils. The part of the plant from which it is extracted, and the English name of the oil, are added in separate columns †.

---

\* Nicholson's *Jour.* vi. 224.

† See Gren's *Handbuch*, ii. 204.



Plants.	Parts.	Oil of	Colour.	Chap. I.
1. <i>Artemisia absinthium</i>	Leaves	Wormwood	Green	List of volatile oils.
2. <i>Acorus calamus</i>	Root	Sweet flag	Yellow	
3. <i>Myrtus Pimenta</i>	Fruit	Jamaica pep. §	Yellow	
4. <i>Anethum graveolens</i>	Seeds	Dill	Yellow	
5. <i>Angelica archangelica</i>	Root	Angelica		
6. <i>Pimpinella anisum</i>	Seeds	Anise	White	
7. <i>Illicium anisatum</i>	Seeds	Stellat. anise	Brown	
8. <i>Artemisia vulgaris</i>	Leaves	Mugwort		
9. <i>Citrus aurantium</i>	Rind of the fruit	Bergamotte	Yellow	
10. <i>Meloleuca leucodendra</i>	Leaves	Cajeput	Green	
11. <i>Eugenia caryophyllata</i>	Capsules	Cloves §	Yellow	
12. <i>Carum carvi</i>	Seeds	Caraways	Yellow	
13. <i>Amomum cardamomum</i>	Seeds	Card. seeds	Yellow	
14. <i>Carlina acaulis</i>	Roots		White	
15. <i>Scandix chaerifolium</i>	Leaves	Chervil	Sulph. yel.	
16. <i>Matricaria chamomilla</i>	Petals	Chamomile	Blue	
17. <i>Laurus cinnamomum</i>	Bark	Cinnamon §	Yellow	
18. <i>Citrus medica</i>	Rind of the fruit	Lemons	Yellow	
19. <i>Cochlearia officinalis</i>	Leaves	Scurvy grass	Yellow	
20. <i>Copaifera officinalis</i>	Extract	Copaiba	White	
21. <i>Coriandrum sativum</i>	Seeds	Coriand. seed	White	
22. <i>Crocus sativus</i>	Pistils	Saffron §	Yellow	
23. <i>Piper cubeba</i>	Seeds	Cubeb pep.	Yellow	
24. <i>Laurus culilaban</i>	Bark	Culilaban	Brown yel.	
25. <i>Cuminum cyminum</i>	Seeds	Cummi	Yellow	
26. <i>Iula helenium</i>	Roots	Elecampane	White	
27. <i>Anethum feniculum</i>	Seeds	Fennel	White	
28. <i>Croton eleutheria</i>	Bark	Cascarilla	Yellow	
29. <i>Maranta galanga</i>	Roots	Galanga	Yellow	
30. <i>Hyssopus officinalis</i>	Leaves	Hyssop	Yellow	
31. <i>Juniperus communis</i>	Seeds	Juniper	Green	
32. <i>Lavendula spica</i>	Flowers	Lavender	Yellow	
33. <i>Laurus nobilis</i>	Berries	Laurel	Brownish	
34. <i>Prunus laurocerasus</i>	Leaves	Lauroceras. §		
35. <i>Levisticum ligusticum</i>	Roots	Lovage	Yellow	
36. <i>Myristica moschata</i>	Seeds*	Mace	Yellow	

§ The oils marked § sink in water.

\* They yield also a fixed oil.

Book IV.	Plants.	Parts.	Oil of	Colour.
37.	<i>Origanum majorana</i>	Leaves	Marjorum	Yellow
38.	<i>Pistacia lentiscus</i>	Resin	Mastich	Yellow
39.	<i>Matricaria parthenium</i>	Plant	Motherwort	Blue
40.	<i>Melissa officinalis</i>	Leaves	Balm	White
41.	<i>Mentha crispa</i>	Leaves		White
42.	—— <i>piperitis</i>	Leaves	Peppermint	Yellow
43.	<i>Achillea millefolium</i>	Flowers	Millefoil	Blue and green
44.	<i>Citrus aurantium</i>	Petals	Neroli	Orange
45.	<i>Origanum creticum</i>	Flowers	Spanish hop	Brown
46.	<i>Apium petroselinum</i>	Roots	Parsley	Yellow
47.	<i>Pinus sylvestris et abies</i>	Wood & resin	Turpentine	Colourless
48.	<i>Piper nigrum</i>	Seeds	Pepper	Yellow
49.	<i>Rosmarinus officinalis</i>	Plant	Rosemary	Colourless
50.	<i>Mentha pulegium</i>	Flowers	Pennyroyal	Yellow
51.	<i>Genista canariensis</i>	Root	Rhodium	Yellow
52.	<i>Rosa centifolia</i>	Petals	Roses	Colourless
53.	<i>Ruta graveolens</i>	Leaves	Rue	Yellow
54.	<i>Juniperus sabina</i>	Leaves	Savine	Yellow
55.	<i>Salvia officinalis</i>	Leaves	Sage	Green
56.	<i>Santalum album</i>	Wood	Santalum	Yellow
57.	<i>Laurus sassafras</i>	Root	Sassafras	Yellow
58.	<i>Satureia hortensis</i>	Leaves	Satureia	Yellow
59.	<i>Thymus serpyllum</i>	Leaves and flower	Thyme	Yellow
60.	<i>Valeriana officinalis</i>	Root	Valerian	Green
61.	<i>Kempferia rotunda</i>	Root	Zedoary	Greenish blue
62.	<i>Amomum Zinziber</i>	Root	Ginger	Yellow
63.	<i>Andropogon schænanthum</i>		Sira	Brown

Several of the gum resins, as *myrrh* and *gamboge*, yield likewise an essential oil, and likewise the balsams as *benzoin*, &c.



## SECT. XX.

## OF WAX.

THE upper surface of the leaves of many trees is covered with a varnish, which may be separated and obtained in a state of purity by the following process :

Digest the bruised leaves, first in water and then in alcohol, till every part of them which is soluble in these liquids be extracted. Then mix the residuum with six times its weight of a solution of pure ammonia, and, after sufficient maceration, decant off the solution, filter it, and drop into it, while it is incessantly stirred, diluted sulphuric acid, till more be added than is sufficient to saturate the alkali. The varnish precipitates in the form of a yellow powder. It should be carefully washed with water, and then melted over a gentle fire \*.

How obtained from plants.

Mr Tingry first discovered that this varnish possessed all the properties of *bees wax* †. Wax, then, is a vegetable product. Several plants contain wax in such abundance as to make it worth while to extract it from them. But let us, in the first place, consider the properties of bees wax, the most common and important species. This substance, as Huber has demonstrated, contrary to the generally received opinion, is prepared

\* Hermbstadt, *Med. and Phys. Jour.* iii. 372.

† *Ess. Meth. Forêt et Bois*, i. 180.

## Book IV.

Properties  
of bees wax.

by the bees from honey or sugar, the latter yielding the greatest proportion of it \*.

1. Wax, when pure, is of a whitish colour ; it is destitute of taste, and has scarcely any smell. Bees wax indeed has a pretty strong aromatic smell ; but this seems chiefly owing to some substance with which it is mixed ; for it disappears almost completely by exposing the wax, drawn out into thin ribands, for some time to the atmosphere. By this process, which is called *bleaching*, the yellow colour of the wax disappears, and it becomes very white. Bleached wax is not affected by the air †.

2. The specific gravity of unbleached wax varies from 0.9600 † to 0.9650 § ; that of white wax from 0.8203 to 0.9662 §.

3. Wax is insoluble in water ; nor are its properties altered though kept under that liquid.

4. When heat is applied to wax it becomes soft ; and at the temperature of 142°, if unbleached, or of 155° if bleached ||, it melts into a colourless transparent fluid, which concretes again, and resumes its former appearance as the temperature diminishes. If the heat be still farther increased, the wax boils and evaporates ; and if a red heat be applied to the vapour, it takes fire and burns with a bright flame. It is this property which renders wax so useful for making candles.

Action of  
alcohol,

5. Wax is scarcely acted on by alcohol when cold, but boiling alcohol dissolves it. This was known to

---

\* Nicholson's Jour. ix. 181.

† Sennebier, *Ann. de Chim.* xii. 60. and *Jour. de Phys.* xxviii. 56.

‡ Bostock, Nicholson's Jour. iv. 130.

§ Fabroni, *Crell's Annals*, 1797, ii. 125.

|| Bostock, Nicholson's Jour. i. 71.

Neumann\*, and has been lately verified by Dr Bo- stock†. Rather more than 20 parts of alcohol are necessary to dissolve one part of wax; and as the solution cools, the greater part of the wax precipitates, and the remainder is thrown down by water‡.

6. Ether has but little action on wax while cold; but when assisted by heat, it takes up about  $\frac{1}{10}$ th of its weight of it, and lets the greatest part precipitate on cooling§.

7. Wax combines readily with fixed oils when assisted by heat, and forms with them a substance of greater or less consistency according to the quantity of oil. This composition, which is known by the name of *cerate*, is much employed by surgeons.

The volatile oils also dissolve it when heated. This is well known, at least, to be the case with oil of turpentine. A part of the wax precipitates usually as the solution cools, but of a much softer consistence than usual, and therefore containing oil.

8. The fixed alkalies combine with it, and form a compound which possesses all the properties of common soap. When boiled with a solution of fixed alkalies in water, the liquid becomes turbid, and after some time the soap separates and swims on the surface. It is precipitated from the alkali by acids in the state of flakes, which are the wax very little altered in its properties||. Punic wax, which the ancients employed in painting in encausto, is a soap composed of 20 parts of wax and

Action of  
Alkalies,

\* Neumann's *Chemistry*, p. 331.

† Nicholson's *Jour.* iv. 233.

‡ *Ibid.*

§ *Ibid.*

|| *Ibid.*, p. 132.

Book IV.

one of soda \*. Its composition was ascertained by M Lorgna †.

When boiled with liquid ammonia, it forms a kind of soapy emulsion. As the mixture cools, the greater part of the compound rises to the surface in the state of white flakes. This soap is scarcely soluble in water ‡.

9. The acids have but little action on wax; even oxymuriatic acid, which acts so violently on most bodies, produces no other change on it than that of rendering it white. This property which wax possesses of resisting the action of acids, renders it very useful as a lute to confine acids properly in vessels, or to prevent them from injuring a common cork.

Composition.

10. Mr Lavoisier, by means of the apparatus which he employed in the analysis of alcohol and oils, and which has been described in the First Part of this Work contrived to burn wax in oxygen gas. The quantity of wax consumed was 21.9 grains. The oxygen gas employed in consuming that quantity amounted to 66.4 grains. Consequently the substances consumed amounted to 88.45 grains. After the combustion, there was found in the glass vessel 62.58 grains of carbonic acid and a quantity of water, which was supposed to amount to 25.87 grains. These were the only products.

Now 62.58 grains of carbonic acid gas contain 41.36 of oxygen and 21.02 of carbon; and 25.87 grains of water contain 21.99 of oxygen and 3.88 of hydrogen

66.55	21.90
-------	-------

Consequently 21.9 parts of wax are composed of 18.4

---

\* Pliny, lib. xxi. c. 14.

† *Jour. de Phys.* Nov. 1785.

‡ Bostock, *Nicholson's Jour.* iv. 134.

of carbon and 3.88 of hydrogen. And 100 parts of Chap. I.  
wax are composed of 82.28 carbon

17.72 hydrogen

---

100.00 \*

But this analysis can only be considered as an approximation to the truth; the quantity of water being only estimated, and that of the gas being liable to uncertainty. There can be no doubt, from the little action of acids on wax, that it contains oxygen as an ingredient. We must therefore consider it as a triple compound of carbon, hydrogen, and oxygen; but the proportions are unknown.

If wax be distilled with a heat greater than  $212^{\circ}$ , there comes over a little water, some acid, a very little fluid and odorous oil: the oil, as the distillation advances, becomes thicker and thicker, till at last it is of the consistency of butter, and for this reason has been called *butter of wax*. There remains in the retort a small quantity of coal, which is not easily reduced to ashes. When the butter of wax is repeatedly distilled, it becomes very fluid, and assumes the properties of volatile oil †.

11. Wax possesses all the essential properties of fixed oil. We must therefore consider it as a fixed oil rendered concrete. Now that species of fixed oils, distinguished by the epithet *fat*, have the property of becoming concrete, and assuming the appearance of wax, when exposed long to the air; in consequence, it is supposed, of the absorption of oxygen. Hence proba-

---

\* Lavoisier, *Jour. de Phys.* xxxi. 59.

† Lemery, *Mém. Par.* 1708. p. 53.



## Book IV.

bly the difference between wax and fixed oils consists in the oxygen which it contains as a component part. The wax at its first formation was in all probability in the state of a fixed oil; but by the absorption of oxygen it gradually concentered into wax. Wax, then, may be considered as a fixed oil saturated with oxygen.

Varieties of  
WAX.

12. It is natural to suppose, if this theory be just, that fixed oil will occur in plants in various states of hardness: and this accordingly is the case. Sometimes it is of the consistency of butter, and this is denominated a *butter*; thus we have the butter of *cacao*, the butter of *coco*, the butter of *galam*. Sometimes it is of a greater consistency, and then is denominated *tallow*; thus we have the tallow of the *croton*, extracted by boiling water from the fruit of the *croton sebifera*. When its consistency is as great as possible, it then takes the appellation of *wax*. Thus we have the *myrtle wax* of America, extracted from the seeds of the *myrica cerifera*, and the *pela* of the Chinese. The species of wax, then, which exist in the vegetable kingdom, may possibly be as numerous as the fixed oils. Let us take a view of some of the most remarkable.

Bees wax is the species whose properties have been described in the former part of this Section.

Myrtle  
WAX.

13. The myrtle wax of North America is obtained from the *myrica cerifera*. We are indebted to Dr Bostock\* and Mr Cadet† for a very exact account of its properties and extraction. The *myrica cerifera* is a shrub which grows abundantly in Louisiana and other parts of North America. It produces a berry about

\* Nicholson's Jour. iv. 230.

† Ann. de Chim. xliv. 162.



the size of a pepper corn. A very fertile shrub yields nearly seven pounds. The berries are picked off, thrown into a kettle, and covered with water to the depth of about half a foot. The kettle is then boiled, and the berries stirred and squeezed against the sides of the vessel. The wax which they contain is melted out and swims on the surface. It is skimmed off, passed through a cloth, dried, melted again, and cast into cakes. From the observations of Cadet, we learn that the wax forms the outer covering of the berries. The wax thus obtained is of a pale green colour. Its specific gravity is 1.0150. It melts at the temperature of  $100^{\circ}$ : when strongly heated it burns with a white flame, produces little smoke, and during the combustion emits an agreeable aromatic odour. Water does not act upon it. Alcohol, when hot, dissolves  $\frac{1}{5}$ th of its weight, but lets most of it fall again on cooling. Hot ether dissolves about  $\frac{1}{4}$ th of its weight; and when slowly cooled, deposits it in crystalline plates, like spermaceti. The ether acquires a green colour, but the wax becomes nearly white. Oil of turpentine, when assisted by heat, dissolves it sparingly. Alkalies act upon it nearly as on bees wax. The same remark applies to acids. Sulphuric acid, when assisted by heat, dissolves about  $\frac{1}{11}$ th of its weight, and is converted into a thick dark brown mass\*. Mr Hatchett has lately detected a substance precisely similar to myrtle wax in lact†. It probably exists in many vegetables.

11. The Chinese extract a wax from various vegetables, which they manufacture into candles, and of

\* Bouteau, Nicholson's *Jour.* iv. 130.

† Analytical Experiments on Lac, *Phil. Trans.* 1804.

Book IV.

which they form many of the delicate ornaments which are brought to Europe \*.

15. Wax has been detected by Proust in the green fecula of many plants ; the cabbage for instance. He thinks that it forms a constituent of the pollen of all flowers, and that the bees collect it along with the gluten of the pollen, which, according to him, serves them for food †. But there is undoubted evidence that wax is actually formed by bees. The observations of Mr John Hunter led him to conclude that it comes from under the scaly rings which cover their hinder parts.

Proust has also detected wax covering the rind of resins, plums, oranges, and other similar fruits ‡. In short, it seems to be one of the most abundant of vegetable principles.

---



---

## SECT. XXI.

### OF CAMPHOR.

History.

THE substance called *campbor*, though unknown to the Greeks and Romans, seems to have been long known in the East. When it was first brought to Europe does not appear, though it seems to have been introduced by the Arabians. *Ætius* is the first person

---

\* See *Phil. Trans.* 1753, p. 253 ; in which Father d'Incarville gives some account of the tallow tree, and mode of extracting the tallow or wax.

† *Jour. de Phys.* lvi. 87. and 121.

‡ *Ibid.*

who takes notice of it. It is mentioned in the writings of Paracelsus, in such a manner as to lead to the supposition that it was in common use in his time. Chemists sometimes arranged it among resins, sometimes among volatile oils \*, till Neumann published his dissertation on it in 1725 †. He there examined its properties in detail, and demonstrated that they differed from those of every other substance; and concluded in consequence, that camphor must be considered as a peculiar vegetable principle. To Neumann, then, we are indebted for the first correct experiments on the properties of camphor.

It comes to Europe chiefly from Japan. It is obtained from the *laurus camphora*, a tree common in the East, by distilling the wood along with water in large iron pots, on which are fitted earthen heads stuffed with straw. The camphor sublimes, and concretes upon the straw in the form of a grey powder ‡. It is afterwards refined in Holland by a second sublimation. The vessels are of glass, and somewhat of the shape of a turnip, with a small mouth above loosely covered with paper. According to Ferber, about  $\frac{1}{4}$ th of pounded chalk is mixed with the crude camphor §; but others assure us that there is no addition whatever employed. According to Lewis, nothing more is necessary than a proper regulation of the fire ||; and Professor Robison, who witnessed the process as well as Neumann, informs us, that the camphor in the subliming vessel is in a liquid state, which it could scarcely be if quick-

How pro-  
cured.

\* Hoffmann, *Observ. Phys. Chym. Select.* p. 44.

† *Phil. Trans.* xxxiii. 3:1.

‡ *Oren's Handb.* ii. 219.

§ Neumann's *Chem.* p. 319.

|| Neumann, *Ibid.*

Book IV. lime were employed, at least in any considerable quantity\*.

Properties. 1. Camphor thus refined is a white brittle substance, having a peculiar aromatic odour, and a strong hot acrid taste. Its specific gravity is 0.9887 †.

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely. When sublimed in close vessels it crystallizes in hexagonal plates or pyramids ‡.

2. It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour §.

Action of  
alcohol

3. It dissolves readily in alcohol, and is precipitated again by water. According to Neumann, well rectified alcohol dissolves three-fourths of its weight of camphor. By distillation the alcohol passes over first, and leaves the camphor. This property affords an easy method of purifying camphor. Dissolve the camphor in alcohol, distil off the spirit, and melt the camphor into a cake in a glass vessel ||. If the alcoholic solution of camphor be diluted with water as much as possible, without causing the camphor to pre-

\* Black's *Lectures*, ii. 351.

† According to Brisson. Dr Shaw states it at 0.996 (*Shaw's Boyle*, ii. 346.); and this has been copied into most of the recent chemical books. Probably it varies in its density considerably.

‡ Romieu.

§ From the experiments of Cadet it appears, that a French pint of water dissolves about 16 grains of camphor, and that the camphor may be precipitated by pure potash. *Ann. de Chim.* lxi. 132.

|| This process, proposed by Lewis (*Neumann's Chem.* p. 310.), is surely preferable to that of Trommsdorf, who precipitates the camphor by water from the alcohol, and then melts it into a cake. See *Orm's Handbuch*, ii. 220.



cipitate, small crystals of camphor resembling feathers gradually form<sup>\*</sup>. Chap. I.

4. Camphor is soluble also in oils, both fixed and volatile. If the solution be made by means of heat, as it cools part of the camphor precipitates, and assumes the form of plumose or feather-like crystals†.

5. Camphor is not acted on by alkalies, either pure or in the state of carbonates. Pure alkalies indeed seem to dissolve a little camphor; but the quantity is too small to be perceptible by any other quality than its odour‡. Neither is it acted on by any of the neutral salts which have hitherto been tried. Oils,  
Alkalies,

6. Acids dissolve camphor without effervescence, and in general it may be precipitated unaltered from the recent solution. Acids.

To Mr Hatchett we are indebted for an accurate investigation of the action of sulphuric acid on camphor. Upon a hundred grains of powdered camphor he poured an ounce of sulphuric acid. The camphor immediately became yellow, and gradually dissolved while the acid changed, first to brownish red, and afterwards to brown. In about an hour the liquid became blackish brown, and began to emit abundance of sulphurous acid gas. In four hours the whole appeared like a thick black liquid, and no other smell except that of sulphurous acid could be distinguished in it. As during two days no farther alteration took place, the alembic containing the solution was put upon a sand bath moderately warm, by which means an additional Sulphuric acid.

\* Ramieu, *Mém. Par.* 1756, p. 43.

† Ramieu, *Ibid.*

‡ Scouillon la Grange, *Ann. de Chim.* xxiii. 153.

Book IV.

quantity of sulphurous acid gas was driven off. After two days the liquid was slowly mixed with six ounces of water. It became reddish brown, a considerable coagulum of the same colour subsided, the sulphurous acid smell became imperceptible, and was succeeded by a smell similar to that of a mixture of the oils of lavender and peppermint. The whole was now slowly distilled. The water which came over had the same smell as the original liquid, and there floated over it a little yellowish oil. A blackish brown mass remained behind, not acted on by water; but alcohol extracted a resinous substance, and acquired a blackish brown colour. What remained was charcoal. Thus, by the action of sulphuric acid, the camphor was decomposed and converted into oil, blackish brown resin, and charcoal. The proportion of each was as follows:

Yellow oil .....	3 grains
Charcoal .....	53
Resinous substance	49

---

 105

Making an increase of five grains, either from water which was retained by the resinous-like substance, or from oxygen with which it had combined.

The resinous-like substance, thus obtained, was in reality a species of artificial tannin. It was very brittle, had the odour of caromel, and an astringent taste. It dissolved in cold water, and the solution precipitated iron, lead, tin, and lime, dark brown. It precipitated gold in the metallic state, threw down isinglass in the state of a blackish insoluble substance, and had the property of converting skin into leather. A small



quantity of nitric acid converted it into the artificial tannin obtained from charcoal by nitric acid\*.

Chap. I.

Nitric acid dissolves camphor readily, and in great abundance. The solution separates into two portions; that which contains the camphor, and most of the acid, floats upon the top of the other in the form of a very pale yellow oil. This solution is known by the name of *oil of camphor*. Water and several metals precipitate the camphor unaltered†. Alcohol combines with the oil of camphor. When this solution of camphor in nitric acid is long kept, a portion of the camphor separates in crystals, and swims on the surface, and a small portion is converted into camphoric acid‡.

Nitric acid.

Muriatic, sulphurous, and fluoric acids, in the state of gas, dissolve camphor. When water is added, the camphor appears unaltered in flakes, which swim on the surface of the water§. It is dissolved also by water impregnated with carbonic acid gas||, by acetic acid¶, and probably by all acids.

Other acids.

7. When heat is applied to camphor it is volatilized. If the heat be sudden and strong, the camphor melts before it evaporates; and it melts, according to Venturi, at the temperature of 300°; according to Romien, at 421°\*\*. It catches fire very readily, and

Action of heat.

\* Huchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

† Neumann's *Chemistry*, p. 321.

‡ Planche found these changes in a vial of oil of camphor, which had been kept unopened for 14 years. *Ann. de Chim.* xliii. 346.

§ Fourcroy.

|| *Jour. de Phys.* lii. 67.

¶ *Phil. Mag.* xv. 156. Aromatic vinegar consists chiefly of this compound.

\*\* *Mem. Par.* 1756, p. 444.

Book IV.

emits a great deal of flame as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder, which has all the properties of charcoal; a quantity of carbonic acid gas is evolved; the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid\*.

If two parts of alumina and one of camphor be formed into a paste with water, and distilled in a glass retort, there comes over into the receiver (which should contain a little water, and communicate with a pneumatic apparatus) a volatile oil of a golden yellow colour, a little camphoric acid, which dissolves in the water, and a quantity of carbonic acid gas and carbureted hydrogen gas, which may be collected by means of a pneumatic apparatus. There remains in the retort a substance of a deep black colour, composed of alumina and charcoal. By this process, from 122·284 parts of camphor, Mr Bouillon la Grange, to whom we are indebted for the whole of the analysis of camphor, obtained 45·856 parts of volatile oil and 30·571 parts of charcoal. The proportion of the other products was not ascertained†.

From this analysis, Mr Bouillon la Grange concludes that camphor is composed of volatile oil and charcoal or carbon combined together. We learn from his ex-

---

\* Bouillon la Grange, *Ann. de Chim.* xxiü. 268.

† *Ibid.* p. 257.

periments, that the ultimate ingredients of camphor are carbon and hydrogen; and that the proportion of carbon is much greater than in oils.

Chap. I.

8. There are several species of camphor which have been examined by chemists, and which differ considerably from each other in their properties. The most remarkable are *common camphor*, the *camphor of volatile oils*, and the *camphor* obtained by treating oil of turpentine with *muratic acid*.

Species of  
camphor:

B. Common camphor, obtained by distillation from the *laurus camphora*, is the substance which has been described in the preceding part of this Section. In Borneo and Sumatra camphor is procured from the *laurus sumatrensis*; but as none of this camphor is brought to Europe, we do not know how far it agrees with common camphor in its properties. The *laurus cinnamomum* likewise yields camphor.

1. Common  
camphor;

10. The second species of camphor seems to exist in a great variety of plants, and is held in solution by the volatile oils extracted from them. Neumann obtained it from oils of thyme, marjoram, cardomum\*; Hermann, from oils extracted from various species of mint†. Cartheuser obtained it from the roots of the *serotia galanga*, *kempferia rotunda*, *amomum zinziber*, *laurus cassia*‡, and rendered it probable that it is contained in almost all the labiated plants. It has been supposed to exist in these plants combined with volatile oil. Proust has shown how it may be extracted,

2. Camphor  
from oils;

\* Phil. Trans. 1725, p. 321.

† Junker's Conspectus Chemicus, ii. 100.

‡ De Generis Quibusdam Plantarum Princip. 1734; as quoted by Gren, Handb., ii. 217.

**Book IV.** in considerable quantity, from many volatile oils\*. All that is necessary, is to expose the oil to the open air at a temperature between  $22^{\circ}$  and  $54^{\circ}$ ; the oil gradually evaporates, and the camphor crystallizes. By this process he obtained from the oil of rosemary  $\frac{1}{8}$ th of its weight of camphor, from that of sweet marjoram  $\frac{1}{10}$ th, from oil of sage  $\frac{1}{4}$ th, and from oil of lavender more than  $\frac{1}{4}$ th. By distilling the oil in a water-bath, some degrees under the boiling point, till one-third of the oil comes over, part of the camphor is found crystallized in the still-vessel. This being removed, and the oil again distilled as before, more camphor crystallizes. By three such processes the whole of the camphor is obtained from the oil. The camphor is then purified by mixing it with a little dry lime, and subliming it.

From the observations of Mr John Brown, there is reason to believe that the camphor from oil of thyme differs from common camphor in several respects. It does not appear to form a liquid solution either with nitric or sulphuric acid; nor is it precipitated from nitric acid in powder like common camphor, but in a glutinous mass†.

3. Artificial camphor.

11. The artificial camphor yielded by oil of turpentine, when saturated with muriatic acid gas, was discovered by Mr Kind, apothecary in Eutin, while employed in making a medicine called the *liquor arthriticus Pottii*. He put a quantity of oil of turpentine into a Woulfe's bottle, and caused a current of muriatic acid gas,

How prepared.

\* *Ann. de Chim.* iv. 179.

† *Phil. Trans.* 1715, xxxiii. 364.



separated from common salt by sulphuric acid, to pass through it. The salt used was of the same weight with the oil of turpentine. At first the oil became yellow, then brown, and at last became almost solid, from the formation of a great number of crystals in it, which possessed the properties of camphor\*. This curious experiment was repeated by Trommsdorf with a similar result. He examined the camphoric crystals obtained, and found them in most respects to agree with common camphor, though in some they differed†. The society of apothecaries at Paris, on being informed of these particulars, appointed Messrs Gluzel, Chomet, and Boullay, to examine the subject. The result of their labours has been given to the world by Boullay‡. They ascertained the proportion of camphor yielded by oil of turpentine, the best dose of muriatic acid gas, examined the properties of the camphoric production, and endeavoured to explain the way in which it had been formed. The experiment of Kind was repeated by Hagen in 1804§; and more lately, a set of experiments on the same subject was made by Gehlen, Schuster, and Pesth, chiefly in order to elucidate the theory of the process||. Thenard has repeated them with the same object¶.

The proportion of muriatic gas found to answer best, is what can be separated by sulphuric acid and heat from a quantity of common salt equal in weight to the oil of turpentine employed. The camphor produced

\* Trommsdorf's *Jour. der Pharmacie*, xi. 232; as quoted in Gehlen's *Jour.* vi. 459.

† Ibid.

‡ *Ann. de Chim.* i. 272.

§ Gehlen's *Jour.* ii. 237.

|| Ibid. vi. 470.

¶ *Mém. d'Arcueil*, ii. 29.



Book IV.

amounts nearly to one-half of the oil of turpentine. The French apothecaries put into a Woulfe's bottle four pounds of oil of turpentine, and into a tubulated retort four pounds of common salt, and two pounds of sulphuric acid, and drove off the muriatic acid gas by means of heat. It was totally absorbed by the oil, the bulk of which was augmented by  $\frac{2}{10}$ th, while it became at the same time very hot. Its colour became brown; it retained its transparency; and drops of oil gradually formed at the bottom of it. In 24 hours it deposited regular crystals; which, being separated from the brown liquid with which they were mixed, and dried on blotting paper, weighed 24 ounces. The liquor being left for some days in a cellar, deposited four ounces more of the same crystals; and by exposure to an artificial cold of about  $14^{\circ}$ , two ounces more were obtained, making a total of 30 ounces, or  $1\frac{1}{4}$  lb. from the four pounds of oil of turpentine. No additional crystals were obtained by increasing the quantity of gas; but the French chemists did not find that the produce of camphor was diminished by this augmentation, as had been concluded by Trommsdorf from his trials.

Properties.

The camphor thus procured was very white; it had a peculiar odour, in which that of the oil of turpentine could be distinguished. When washed with water, it became beautifully white, and gave no longer signs of containing an acid, but still had the smell of oil of turpentine. Water containing some carbonate of potash deprived it of part of this odour, but not the whole. When mixed with its own weight of charcoal powder, wood-ashes, quicklime, or porcelain clay, and sublimed, it was obtained in a state of purity.

Its smell when pure resembles that of common cam-

phor, but is not so strong. Its taste also resembles that of camphor. It swims on water, to which it communicates its taste, and burns upon its surface. It dissolves completely in alcohol, and is precipitated by water. Nitric acid, of the specific gravity 1.261, had no action on it, though it readily dissolves common camphor; but concentrated nitric acid dissolves it with the disengagement of nitrous gas; and water does not precipitate it from its solution as it does common camphor. Acetic acid does not dissolve it. When heated it sublimes without decomposition; and when set on fire burns like camphor.

Such are the properties of this artificial camphor, as far as they have been investigated. We see from them that it resembles common camphor, except as far as regards the action of acids. In the experiment of Thénard, the residual liquid was not brown but colourless. He ascribes the brown colour of it, in preceding experiments, to the oil of turpentine used containing some resin mixed with it, whereas his had been purified by distilling it. According to him the oil of turpentine is not decomposed by this process. The residual liquid he thinks may be owing to the presence of some foreign oil in oil of turpentine. When this residual liquid is exposed to the air for some days it loses its acid properties, though it still contains abundance of acid. But the acid is neutralized by the oil.

Action of  
muriatic  
acid gas on  
oil of tur-  
pentine.

Gehlen ascertained that neither fluoric acid gas, sulphurous acid gas, nor ammoniacal gas, produce any such decomposition in oil of turpentine. Neither is any such change produced by the action of oxymuriatic acid

**Book IV.** gas \*; but when oil of turpentine is distilled slowly at a heat of 122°, a number of crystals of camphor sublime from it †. No other oils tried yielded camphor when impregnated with muriatic acid gas ‡.

12. Camphor is much used in medicine. It is a powerful stimulant; it is considered as peculiarly efficacious in diseases of the urinary organs; it is often serviceable in mania, and procures sleep when every other medicine fails.

---

## SECT. XXII.

### OF BIRD-LIME.

**Discovery.** THE vegetable principle to which I give the name of *bird-lime*, was first examined by Vanquelin, who found it possessed of properties different from every other. It was found collected on the epidermis of a plant brought to Europe by Michaud, and called *robinia viscosa* by Cels; constituting a viscid substance, which made the fingers adhere to the young twigs§. From the late analysis of *bird-lime* by Bouillon la Grange, it is obvious that it owes its peculiar properties to the presence of an analogous substance, which indeed constitutes the essen-

---

\* Boullay, *Ann. de Chim.* li. 283.

† Boullay, *Ibid.*

‡ *Ibid.*

§ *Ann. de Chim.* xxiil. 223.

tial part of that composition \*. Hence the reason why I have given the name of *bird-lime* to the principle itself.

Chap. I.

1. Natural bird-lime (or that which exudes spontaneously from plants) possesses the following properties:

2. Natural  
bird-lime.

Its colour is green; it has no sensible taste or smell; is extremely adhesive; softens by the heat of the fingers, and sticks to them with great obstinacy. When heated it melts, swells up, and burns with a considerable flame, leaving a bulky charcoal behind it. It does not dissolve in water; alcohol has but little action on it, especially when cold. By the assistance of heat it dissolves a portion of it; but on cooling, allows the greatest part to precipitate again. When exposed to the air it continues glutinous, never becoming hard and brittle like the resins.

It combines readily with oils. Ether is its true solvent, dissolving it readily without the assistance of heat. The solution is of a deep green colour. The alkalis do not combine with it; the effect of the acids was not tried †. These properties are sufficient to distinguish bird-lime from every other vegetable principle.

It is not unlikely that the viscid substance which covers the stem of the *lychnis viscaria*, *saxifraga tri-dactylites*, and a few other plants common in this country, consists of this vegetable principle. It has not hitherto, as far as I know, been examined by any chemist.

2. Artificial bird-lime is prepared from different

2. Artificial  
bird-lime.

\* Nicholson's Jour. xiii. 144.

† Vauquelin, Ann. de Chim. xviii. 224.



## Book IV.

substances in different countries. The berries of the mistletoe are said to have been formerly employed. They were pounded, boiled in water, and the hot water poured off. At present bird-lime is usually prepared from the middle bark of the holly. The process followed in England, as described by Geoffroy, is as follows: The bark is boiled in water seven or eight hours till it becomes soft. It is then laid in quantities in the earth, covered with stones, and left to ferment or for a fortnight or three weeks. By this fermentation it changes to a mucilaginous consistency. It is then taken from the pits, pounded in mortars to a paste, and well washed with river water. Bouillon la Grange informs us, that at Nogent le Rotrou bird-lime is made by cutting the middle bark of the holly into small pieces, fermenting them in a cool place for a fortnight, and then boiling them in water, which is afterwards evaporated. At Commerci various other plants are used.\*

Bouillon la Grange made bird-lime for the purpose of analysis by the following process. He bruised a sufficient quantity of the middle bark of the holly, boiled it in water for four or five hours, and then deposited it in pits placed in earthen pans, where it continued, being moistened occasionally with water till it became viscous. Lastly, it was freed from all heterogeneous substances by washing it with pure water. Thus prepared, it resembled the bird-lime of Commerci very exactly †.

## Properties.

Its colour is greenish, its flavour sour, and its consistence gluey, stringy, and tenacious. Its smell is a

---

\* Nicholson's *Jour.* xlii. 145.

† Bouillon la Grange, Nicholson's *Jour.* *ibid.*



milar to that of linseed oil. When spread on a glass plate and exposed to the air and light it dries, becomes brown, loses its viscosity, and may be reduced to powder; but when water is added to it, the glutinous property returns. It reddens vegetable blues.

When gently heated it melts and swells, and emits an odour like that of animal oils. When heated on red hot coals, it burns with a lively flame, and gives out a great deal of smoke, leaving a white ash, composed of carbonate of lime, alumina, iron, sulphate, and muriate of potash.

Water has little action on bird-lime. When boiled in water the bird-lime becomes more liquid, but recovers its original properties when the water cools. The water, by this treatment, acquires the property of reddening vegetable blues, and when evaporated leaves a mucilaginous substance, which may be likewise separated by alcohol.

A concentrated solution of potash forms with bird-lime a whitish magma, which becomes brown by evaporation, while ammonia separates. The compound thus formed is less viscid than bird-lime, and in smell and taste resembles soap. In alcohol and water it dissolves almost completely, and possesses properties similar to those of soap.

Weak acids soften bird-lime and partly dissolve it; strong acids act with more violence. Sulphuric acid renders it black; and when lime is added to the solution, acetic acid and ammonia separate. Nitric acid cold has little effect; but when assisted by heat it dissolves the bird-lime; and the solution, when evaporated, leaves behind it a hard brittle mass. By treating this mass with nitric acid, a new solution may be ob-

## Book IV.

tained, which by evaporation yields malic and oxalic acids, and a yellow matter which possessed several of the properties of wax. Cold muriatic acid does not act on bird-lime; hot muriatic acid renders it black.

Bird-lime, when treated with oxymuriatic acid, became white, and is divided into hard compact masses having unaltered bird-lime in their centre. This white substance may be pulverised; it is insoluble in water, does not melt when heated; and when treated with nitric acid, it neither becomes yellow, nor does it yield resin.

Acetic acid softens bird-lime, and dissolves a certain portion of it. The liquid acquires a yellow colour. Its taste is insipid. When carbonate of potash is dropped into this solution, no precipitate falls. By evaporation it yields a resinous like substance.

Some of the metallic oxides are reduced when heated with bird-lime. Litharge combines with it, and forms a kind of plaster.

Alcohol of the specific gravity 0.817 dissolves bird-lime at a boiling heat. On cooling it lets fall a yellow matter similar to wax. The filtered liquid is bitter, nauseous, and acid. Water precipitates a substance similar to resin.

Sulphuric ether dissolves bird-lime readily, and in great abundance. The solution is greenish. When mixed with water, an oily substance separates, which has some resemblance to linseed oil. When evaporated a greasy substance is obtained, having a yellow colour and the softness of wax. Oil of turpentine dissolves bird-lime readily.

Such are the properties of artificial bird-lime, as far

as they have been investigated by Bouillon La Grange\*. It is obvious that it contained acetic acid, mucilage, and several alkaline and earthy bodies, which must be considered as foreign substances. When these are removed, the close analogy between artificial and natural bird-lime is sufficiently obvious.

---

### SECT. XXIII.

#### OF RESINS.

It is at present the opinion of chemists, that *resins* stand in the same relation to the *volatile* oils that *wax* does to the *fixed*. Wax is considered as a fixed oil saturated with oxygen; resins, as volatile oils saturated with the same principle.

The resins are very numerous; and on account of the various purposes to which they are applied, and the peculiarity of their properties, constitute one of the most important genera of vegetable substances. Till lately they have been very much overlooked by chemists, who satisfied themselves with picking up doubtful information from artists and manufacturers. Many erroneous opinions concerning them have of course been admitted into every system of chemistry. The subject has lately engaged the attention of Mr Hatchett, whose consummate skill and happy talent for observation pe-

---

\* Nicholson's *Journal*, viii. 246.

## Book IV.

cularly fitted him for the task. To that gentleman I am indebted for some of the most important facts in this Section.

## Origin.

Resins often exude spontaneously from trees; they often flow from artificial wounds, and not uncommonly are combined at first with volatile oil, from which they are separated by distillation. The reader can be at no loss to form a notion of what is meant by *resin*, when he is informed that common *rosin* furnishes a very perfect example of a resin, and that it is from this substance that the whole genus derived their name: for rosin is frequently denominated *resin*.

I. Resins may be distinguished by the following properties:

## Properties.

1. They are solid substances, naturally brittle; have a certain degree of transparency, and a colour most commonly inclining to yellow. Their taste is more or less acrid, and not like that of volatile oils; but they have no smell unless they happen to contain some foreign body. They are all heavier than water. They are all non-conductors of electricity; and when excited by friction, their electricity is negative.

## Specific gravity.

2. Their specific gravity varies considerably. The following Table exhibits a view of the specific gravity of such of the resins as have been hydrostatically examined\*.

Elemi.....1·0182

Anime.....1·0284

---

\* The specific gravities in the text were ascertained by Brisson. Older writers differ so much from each other, that there is reason to suspect that the substances tried were not always those to which we at present give the same names.



Copal .....	1.0452
Tacamahac....	1.0463
Rosin .....	1.0727
Mastich.....	1.0742
Sandarich.....	1.0920
Lac.....	1.1390
Labdanum.....	1.1802

3. When exposed to heat they melt; and if the heat be increased they take fire, and burn with a strong yellow flame, emitting at the same time a vast quantity of smoke. Action of heat,

4. They are all insoluble in water whether cold or hot; but when they are melted along with water, or mixed with volatile oil, and then distilled with water, they seem to unite with a portion of that liquid; for they become opaque, and lose much of their brittleness. This at least is the case with common rosin. Water,

5. They are all, with a few exceptions, soluble in alcohol, especially when assisted by heat. The solution is usually transparent; and when the alcohol is evaporated, the resin is obtained unaltered in its properties. Alcohol, according to Tingry, never takes up more than one-third of its weight of resin. When the solution is mixed with water, it becomes milky, and the resin falls in the state of a white powder. They are soluble also in sulphuric ether. Alcohol and ether,

6. Several of them are soluble in fixed oils, especially in the drying oils. The greater number are soluble in the volatile oils; at least in oil of turpentine, the one commonly employed. Oils,

7. Mr Hatchett first examined the action of fixed alkalies on resins, and ascertained, contrary to the received opinion of chemists, that alkaline leys dissolve Alkalies,



Book IV.

them with facility. He reduced a quantity of common rosin to powder, and gradually added it to a boiling lixivium of carbonate of potash; a perfect solution was obtained of a clear yellow colour, which continued permanent after long exposure to the air. The experiment succeeded equally with carbonate of soda, and with solutions of pure potash or soda. Every other resin tried was dissolved as well as *rosin*. Nothing can afford a more striking proof than this, of the necessity of repeating the experiments of our predecessors before we put implicit confidence in their assertions. Mr Hatchett's discovery must lead to very important consequences. The well-known fact, that the soap-makers in this country constantly mix *rosin* with their soap; that it owes its yellow colour, its odour, and its easy solubility in water to this addition, ought to have led chemists to have suspected the solubility of resin in alkalis. No such consequence, however, was drawn from this notorious fact.

These alkaline solutions of resins have the properties of soap, and may be employed as detergents. When mixed with an acid, the resin is separated in flakes usually of a yellow colour, and not much altered in its nature.

Ammonia acts but imperfectly upon resins, and does not form a complete solution of any of those bodies hitherto tried.

Acids.

8. It was the received opinion of chemists that acids do not act upon resins. This opinion seems to have been founded on the known effects of nitric acid upon oils, and on the old theory derived from that action

that resins are compounds of an oil and an acid \*. Mr Hatchett first ascertained this opinion also to be erroneous, and showed that most of the acids dissolve resins with facility, producing different phenomena according to circumstances. Chap. I.

When sulphuric acid is poured upon any of the resins in powder, it dissolves them in a few minutes. At first the solution is transparent, of a yellowish brown colour, and of the consistency of a viscid oil, and the resin may be precipitated nearly unaltered by the addition of water. If the solution be placed on a sand bath, its colour becomes deeper, sulphurous acid gas is emitted, and it becomes very thick, and of an intense black †. If the solution, some time after it is completed, and before it has acquired the deep black colour, beedulcorated, and the residuum digested in alcohol, and the alcohol afterwards separated by distillation, the residue is in part soluble in cold water, and the portion dissolved possesses the properties of artificial tannin ‡. Thus it appears, that sulphuric acid dissolves resins, but gradually acts upon them after the solution is completed, converting them first into artificial tannin, and afterwards reducing them to charcoal: for the last black state of the solution is owing to the evolution of this substance. The charcoal thus formed is dense, and burns rather like mineral than vegetable coal. Its quantity also is very considerable. The following Table exhibits a view of the proportion of charcoal obtained by Mr Hatchett, by digesting different resins in sulphuric acid, Sulphuric acid,

\* See Hoffman, *Observ. Phys. Chym. Select.* p. 55.

† Hatchett on an artificial Tanning Substance, *Phil. Trans.* 1805.

‡ Hatchett's Third Series of Experiments, *Ibid.* 1806.

Book IV. edulcorating the residue, and separating the tan means of alcohol and water \*. The quantity employed was always 100 grains.

Charcoal evolved.

Copal.....	67 grains.
Mastich .....	66
Elemi.....	63
Tacamahac .....	62
Amber .....	56
Rosin.....	43

The quantity of charcoal formed by this process is very remarkable. The same substances, when treated in the usual way by exposure to a red heat in retort vessels, yield very little charcoal. The following table exhibits the quantity obtained by Mr Hatchett from 100 grains of several of them † :

Mastich.....	4.50 grains
Amber.....	3.50
Rosin.....	0.65

**Nitric acid.** Nitric acid likewise dissolves the resins with effervescence, but not without changing their nature. Mr Hatchett was first led to examine the action of this acid on resins by observing that resins are thrown down by alkalis from their solutions in alkalies in the state of precipitate ; but when nitric acid is added in excess the whole of the precipitate is redissolved in a boiling solution. This remarkable fact, which did not hold when sulphuric or muriatic acids were used, led him to conclude that the resins were soluble in nitric acid. He

\* Hatchett's Third Series of Experiments, *Phil. Trans.* 1801.

† Hatchett, *Ibid.*

nitric acid of the specific gravity 1.33, on powdered resin in a tubulated retort; and by repeated distillation formed a complete solution of a brownish yellow colour. The solution took place much sooner in an open matrass than in close vessels. The solution continues permanent, though left exposed to the air. It becomes turbid when water is added; but when the mixture is boiled, the whole is redissolved. When Mr Hatchett collected the precipitate thrown down by water by filtration, he found that it still possessed several of the properties of resin. The resin is thrown down from nitric acid by potash, soda, and ammonia; but an excess of these alkalies redissolves the precipitate, and forms brownish orange-coloured liquids. When Mr Hatchett dissolved resin in boiling nitric acid, the solution was attended with a copious discharge of nitrous gas; and when the powdered resin was thrown into cold nitric acid, a considerable effervescence soon took place, and a porous mass was formed, commonly of a deep orange colour.

When the digestion of nitric acid upon a resinous substance is continued long enough, and the quantity of acid is sufficient, the dissolved resin is completely changed; it is not precipitated by water; and by evaporation, a viscid substance of a deep yellow colour is obtained, equally soluble in water and alcohol, and seemingly intermediate between resin and extractive\*. If the abstraction of nitric acid be repeated, this substance gradually assumes the properties of artificial tan-

Tannin  
formed.

\* Hatchett on an Artificial Tanning Substance, *Phil. Trans.* 1805.



**Book IV.** nin \*. Thus it appears that nitric acid gradually alters the nature of resin, producing a suite of changes which terminate in artificial tannin, upon which nitric acid has no action.

**Acetic acid.** Muriatic acid and acetic acid dissolve resin slowly, and it may be precipitated again from them unaltered. Mr Hatchett, to whom we are indebted for the knowledge of all these solutions, recommends acetic acid as an excellent solvent of resins for vegetable analyses. He employed it himself with much address in his analysis of the different varieties of lac †.

**Distillation.** 9. When resins are subjected to destructive distillation, we obtain, according to Gren, carbureted hydrogen and carbonic acid gas, a very small portion of acidulous water, and much empyreumatic oil. The charcoal is light and brilliant, and contains no alkali ‡.

**Supposed to be volatile oils united to oxygen.** 10. When volatile oils are exposed for some time to the action of the atmosphere, they acquire consistency, and assume the properties of resins. During this change they absorb a quantity of oxygen from the air. Westrumb put 80 grains of oil of turpentine into 40 cubic inches of oxymuriatic acid gas. Heat was evolved; the oil gradually evaporated, and assumed the form of yellow resin §. Mr Proust observed, that when volatile oil is exposed to the air, it is partly converted into a resin, and partly into a crystallized acid; usually the benzoic or the camphoric. Hence we see that the oil is converted into two distinct substances. During this

\* Hatchett's Additional Experiments on Artificial Tannin, *Phil. Trans.* 1805.

† *Phil. Trans.* 1804.

‡ *Handbuch*, ii. 140.

§ *Crell's Annals*, i. 1790.



change oxygen is absorbed ; and Fourcroy has observed that a portion of water is also formed \*. It is probable, from these facts, that resin is volatile oil deprived of a portion of its hydrogen, and combined with oxygen. The experiments of Mr Hatchett have added much to the plausibility of this theory.

Chap. I.

11. Hermbstadt affirms, that to know whether any vegetable substance contains resin, we have only to pour some sulphuric ether upon it in powder, and expose the infusion to the light. If any resin be present, the ether will assume a brown colour.

12. Having now described the general properties of resinous bodies, it will be proper to take a more particular view of those of them which are of the most importance, that we may ascertain how far each possesses the general characters of resins, and by what peculiarities it is distinguished from the rest. The most distinguished of the resins are the following :

List of resins.

1. *Rosin*.—This substance is obtained from different species of *fir* ; as the *pinus abies*, *sylvestris*, *larix*, *balsamea*. It is well known that a resinous juice exudes from the *pinus sylvestris*, or common Scotch fir, which hardens into tears. The same exudation appears in the *pinus abies*, or spruce fir. These tears constitute the substance called *thus*, or common frankincense. When a portion of bark is stripped off these trees, a liquid juice flows out, which gradually hardens. This juice has obtained different names according to the plant from which it comes. The *pinus sylvestris* yields common turpentine ; the *larix*, Venice turpentine ; the *balsamea*,

Rosin.

\* Fourcroy, vili. 16.

Boit IV.

*Saliam of Canada, &c.* All these juices, which are commonly distinguished by the name of turpentine, are considered as composed of two ingredients; namely oil of turpentine and resin. When the turpentine is distilled, the oil comes over, and the resin remains behind. When the distillation is continued to dryness, the residuum is known by the name of common resin, or colophonium; but when water is mixed with it while yet fluid, and incorporated by violent agitation, the mass is called *yellow resin*. During winter the wounds made in the fir trees become encrusted with a white brittle substance called *barras* or *galipot*, consisting of resin united to a small portion of oil. The yellow resin made by melting and agitating this substance in water is preferred for most purposes; because it is more ductile, owing probably to its still containing some oil\*. The properties of resin are those which have been detailed in the former part of this Section. Its uses are numerous and well known.

*Mastic.*

2. *Mastic.*—This resin is obtained from the *pistacia lentiscus*; a tree which grows in the Levant, particularly in the island of Chios. When transverse incision are made into this tree, a fluid exudes, which soon concretes into yellowish semitransparent brittle grains. In this state it is sold under the name of mastic. It softens when kept in the mouth, but imparts very little taste. This has induced surgeons to employ it to fill up the cavities of carious teeth, which it does tolerably well. When heated, it melts and exhales fragrant odour. Its taste is slight, but not unpleasant.

---

\* *Neumann's Chemistry*, p. 286.

† *Ibid.* p. 297.

stant. In Turkey great quantities of it are said still to be chewed for sweetening the breath, and strengthening the gums. It is to this use of the resin as a masticatory that it is supposed to owe its name \*. Mastich does not dissolve completely in alcohol; a soft elastic substance separates during the solution. This substance, in Neumann's experiments, amounted to about  $\frac{1}{4}$ th of the mastich †; but in those made more lately by Mr Matthews, it was nearly a fifth ‡. The nature of this insoluble portion was first examined by Kind §, who found it possessed of all the properties of caoutchouc. These experiments have lately been repeated by Mr Matthews with a similar result ||. Mr Brande, however, has observed, that when this insoluble substance is dried it becomes brittle, in which respect it differs from caoutchouc. He has observed also, that by passing a current of oxymuriatic gas through the alcoholic solution of mastich, a tough elastic substance is thrown down, precisely similar to the original insoluble portion \*\*. When mastich is distilled either with water or alcohol, nothing considerable comes over with these liquids; but Hoffmann ascertained, that if the resin be first mixed in a mortar with its own weight of carbonate of potash, and afterwards distilled with alco-

Contains  
caoutchouc.

\* See Neumann's *Chemistry*, p. 298.

† Ibid.

‡ Nicholson's *Jour.* x. 247.

§ Crell's *Annals*, 1794, ii. 185.

|| Nicholson's *Jour.* x. 247.

\*\* *Phil. Mag.* lxx. 116. From these experiments, together with those of Dr Wallaston on this substance, there can be little doubt that it is a peculiar vegetable principle. It may be characterized thus: Brittle, semitransparent, fusible like resins, insoluble in water and alcohol, soluble in ether.

- Book IV. hol, the liquid comes over both with the smell and taste of mastich \*. With the other agents it exhibits the phenomena described in the former part of this Section.
- Sandarach. 3. *Sandarach*.—This resin is obtained from the *juniperus communis* or common juniper. It exudes spontaneously, and is usually in the state of small round tears of a brown colour, and semitransparent, not unlike mastich, but rather more transparent and brittle. When chewed it does not soften as mastich does, but crumbles to powder. Mr Matthews found it almost completely soluble in eight times its weight of alcohol. The residue was extraneous matter †. It does not dissolve in tallow or oil, as common resin does ‡. Mr Hatchett found it soluble in alkalies and acids with the same phenomena as common resin §.
- Elemi. 4. *Elemi*.—This resin is obtained from the *amygdalifera*; a tree which grows in Canada and Spanish America. Incisions are made in the bark during dry weather, and the resinous juice which exudes is left to harden in the sun. It comes to this country in long roundish cakes wrapped in flag leaves. It is of a pale yellow colour, semitransparent; at first softish, but it hardens by keeping. Its smell is at first strong and

---

\* Hoffmann, *Observ. Phys. Chim. Select.* p. 68.

† Nicholson's *Jour.* x. 246.      § Ibid.

‡ Giese, an apothecary of Augsburg, announced in Scherer's *Journal* for 1802, p. 536, that sandarach does not dissolve completely in alcohol; that the residue amounts to about one-fifth of the whole. This residue he considers as a peculiar substance. Mr Matthews proved, by a set of experiments, that the whole of this statement is inaccurate. I have no doubt that Giese employed mastich instead of sandarach, and that the insoluble substance detected was caoutchouc.

fragrant, but it gradually diminishes. Neuman found that alcohol dissolved  $\frac{1}{10}$ ths of this substance; the remainder consisted chiefly of impurities, and was partly taken up by water. Both water and alcohol, when distilled with it, come over strongly impregnated with its flavour. Along with the water there comes over a fragrant volatile oil, which amounts to about  $\frac{1}{10}$ th of the resin employed\*.

5. *Tacamahac*.—This resin is obtained from the *fagara octandra*, and likewise, it is supposed, from the *populus balsamifera*. It comes from America in large oblong masses wrapt in flag leaves. It is of a light brown colour, very brittle, and easily melted when heated. When pure it has an aromatic smell between that of lavender and musk. When distilled along with water or alcohol, nothing comes over with these liquids. When pure it dissolves completely in alcohol, and water has no action on it†.

6. *Animé*.—This resin is obtained from the *bymenea carbaril* or locust tree, which is a native of North America. Animé resembles copal very much in its appearance; but is readily soluble in alcohol, which copal is not: this readily distinguishes them. It is said to be very frequently employed in the making of varnishes. Alcohol dissolves it completely. Water, according to the experiments of Neumann, dissolves about  $\frac{1}{10}$ th of it; and when the decoction is evaporated, it leaves an unctuous mass, which makes the fingers oily. Alcohol distilled over it acquires both the smell

\* Neumann's Chem. p. 296.

† Ibid. p. 295.



**Book IV.** and taste of animé. Water distilled from it shows on its surface a small quantity of volatile oil \*.

**Ladanum.** 7. *Ladanum* or *labdanum*.—This resin is obtained from the *cistus creticus*, a shrub which grows in Syria and the Grecian Islands. The surface of this shrub is covered with a viscid juice, which, when concremented, forms ladanum. It is collected while moist by drawing over it a kind of rake with thongs fixed to it. From these thongs it is afterwards scraped with a knife. It is always mixed with dust and sand, sometimes in great abundance. The best is in dark coloured masses, almost black, and very soft, having a fragrant odour and a bitterish taste. The impurities, even in the best kinds, amount to about  $\frac{1}{4}$ th. Water dissolves rather more than  $\frac{1}{10}$ th of the pure portion, and the matter taken up is said to possess gummy properties. When distilled with water, a small quantity of volatile oil rises. Alcohol likewise comes over impregnated with the taste and smell of labdanum †.

**Botany Bay resin.** 8. *Botany Bay resin*.—This resin is said to be the produce of the *acarois resinifera*; a tree which grows abundantly in New Holland, especially near Botany Bay. Specimens of it were brought to London about the year 1799, where it was tried as a medicine. Some account was given of it in Governor Philips's Voyage ‡, and in White's Journal of a Voyage to New South Wales ||; but it is to Professor Lichtenstein that we are indebted for an account of its chemical properties. He

\* Neumann's *Chem.* p. 297.

† Duncan's *New Dispensatory*, p. 60.

‡ Ibid. p. 295.

§ Appendix, p. 245.

obtained specimens from London, and published the result of his experiments in Crell's Journal †.

The resin exudes spontaneously from the trunk of the singular tree which yields it, especially if the bark be wounded. It is at first fluid, but becomes gradually solid when dried in the sun. According to Governor Phillips, it is collected usually in the soil which surrounds the tree, having doubtless run down spontaneously to the ground. It consists of pieces of various sizes of a yellow colour, unless when covered with a greenish grey crust. It is firm, yet brittle; and when pounded, does not stick to the mortar nor cake. In the mouth it is easily reduced to powder without sticking to the teeth. It communicates merely a slight sweetish astringent taste. When moderately heated, it melts; on hot coals it burns to a coal, emitting a white smoke, which has a fragrant odour somewhat like storax. When thrown into the fire, it increases the flame like pitch. It communicates to water the flavour of storax, but is insoluble in that liquid. When digested in alcohol, two-thirds dissolve: the remaining third consists of one part of extractive matter, soluble in water, and having an astringent taste; and two parts of woody fibre and other impurities, perfectly tasteless and insoluble. The solution has a brown colour, and exhibits the appearance and the smell of a solution of benzoin. Water throws it down unaltered. When distilled, the products were water, and empyreumatic oil, and charcoal; but it gives no traces of any acid, alkali, or salt, not even when distilled with water.

Properties

Book IV.  
Action of  
soda,

And nitric  
acid.

Twelve parts were boiled in a solution of pure soda in water \*. Two parts of the resin were dissolved, the remaining ten parts were floating on the surface, cohering together in clots. No crystals were obtained by evaporating part of the solution; and when nitric acid was dropt into another portion, resin was unaltered. When mixed with twice its weight of nitric acid, the resin swims unaltered on the surface, but when heat is applied, a considerable effervescence takes place. The digestion was continued till the effervescence stopped, and the resin swam on the surface, the liquid collected together in clots. It was separated by filtration. It had lost  $\frac{1}{4}$ th of its weight. The resin thus treated had acquired a bitter taste, was not so easily melted as before, and alcohol was unable of dissolving only one-half of it. The residue was brown, tasted like bitter almonds; and when mixed with water, let fall a yellow resinous precipitate, and a very bitter taste. The insoluble portion mixed with water, but formed a turbid liquid, which passed through the filter. The nitric acid solution separated from the resin by filtration was transparent; its colour was yellow; its taste bitter; and it tinged substances dissolved in it of a yellow colour. By evaporation it yielded a solid, and deposited a yellow earthy-like powder. The last substance was insoluble in water, and scarcely soluble in alcohol. Its taste was exquisitely bitter, like quassia. It mixed with the saliva, and readily dyed the skin and paper yellow. The residuum consisted of a yellow earthy-like powder.

---

\* By pure *sodasolue*, it is impossible to say whether Lichen is the carbonate of soda or pure soda.

bitter and yellow; but yielded no precipitate with potash and nitrate of lime\*.

I have been thus particular in my account of Lichtenstein's experiments, on account of the very curious results which he obtained. Had he employed stronger reagents and greater heat, he would have most probably anticipated the curious discoveries of Hatchett. The bitter substance, into which he converted this resin by nitric acid, deserves particular attention. He suspects that it is capable of producing the same changes on all the resins: a conjecture which he verified with regard to *colophonium*, as he found it to yield equally a yellow bitter substance. We now know from the experiments of Hatchett, that the action of nitric acid on the resins terminates in the formation of artificial tannin, which possesses a very bitter taste.

9. *Black poplar resin*.—In the year 1770 the black poplar was pointed out, in a German periodical work, as a tree from which abundance of wax could be obtained. It was even said, that a manufactory of candles from the wax of this tree had been established in Italy. This account having been revived in 1804, Schröder was induced to make a set of experiments on the subject. He found, that when the buds of this tree are boiled in water and properly pressed, they yield about  $\frac{1}{4}$ th of their weight of a yellowish white substance, which possesses the properties of a resin, and resembles, according to him, the yellow resin of Botany Bay. When digested in water, a coloured solution is obtained which reddens litmus paper, which becomes

Black poplar resin.

\* Lichtenstein, *Crell's Jour.* 1799, ii. 241.



Book IV. } muddy by cooling, and which when evaporated deposits small crystals \*.

Green resin. 10. The *green resin*, which constitutes the colouring matter of the leaves of trees, and almost all vegetables, is insoluble in water, and soluble in alcohol. From the experiments of Proust we learn, that when treated with oxymuriatic acid it assumes the colour of a withered leaf, and acquires the resinous properties in greater perfection †.

Copal, 11. *Copal*.—This substance, which deserves particular attention from its importance as a varnish, and which at first sight seems to belong to a distinct class from the resins, is obtained, it is said, from the *rubus copallinum*, a tree which is a native of North America; but the best sort of copal is said to come from Spanish America, and to be the produce of different trees. No less than eight species are enumerated by Hernandez ‡.

Copal is a beautiful white resinous substance, with a slight tint of brown. It is sometimes opaque, and sometimes almost perfectly transparent. When heated it melts like other resins; but it differs from them in not being soluble in alcohol, nor in oil of turpentine without peculiar management. Neither does it dissolve in the fixed oils with the same ease as the other resins. It resembles gum animé a little in appearance; but is easily distinguished by the solubility of this last in alcohol, and by its being brittle between the teeth, whereas animé softens in the mouth §. The specific gravity of copal varies, according to Brisson, from

\* Schrader, Gehlen's Jour. vi. 598.

† Jour. de Phys. lvi. 206.

‡ Lewis, Neumann's Chem. p. 299.

§ Ibid.



Chap. I.

1045 to 1139. Mr Hatchett found it soluble in alkalies and nitric acid with the usual phenomena; so that in this respect it agrees with the other resins. The solution of copal in alkalies he found indeed opalescent, but it is nevertheless permanent. It deserves attention, that he found rosin, when dissolved in nitric acid, and then thrown down by an alkali, to acquire a smell resembling that of copal.

When copal is dissolved in any volatile liquid, and spread thin upon wood, metal, paper, &c. so that the volatile menstruum may evaporate, the copal remains perfectly transparent, and forms one of the most beautiful and perfect varnishes that can well be conceived. The varnish thus formed is called *copal varnish*, from the chief ingredient in it. This varnish was first discovered in France, and was long known by the name of *varnis martin*. The method of preparing it is concealed; but different processes for dissolving copal in volatile menstrua have been from time to time made public. The following are the most remarkable of these:

Forms the best varnish.

When copal is kept melted till a sour smelling aromatic odour has ceased to proceed from it, and then mixed with an equal quantity of linseed oil, which has been deprived of all colour by exposure to the sun, it unites with the oil, and forms a varnish which must be dried in the sun\*.

Solution in linseed oil.

I have been informed by a very ingenious japan manufacturer in Glasgow, that the copal varnish used by the English jappanners is made as follows: Four parts by weight of copal in powder are put into a glass ma-

Japaners' varnish.

## Book IV.

trass and melted. The liquid is kept boiling till the fumes, condensed upon the point of a tube thrust into the matrass, drop to the bottom of the liquid without occasioning any hissing noise, as water does. This is a proof that all the water is dissipated, and that the copal has been long enough melted. One part of boiling hot linseed oil (previously boiled in a retort without any litharge) is now poured into it, and well mixed. The matrass is then taken off the fire, and the liquid, while still hot, is mixed with about its own weight of oil of turpentine. The varnish thus made is transparent, but it has a tint of yellow, which the jappanners endeavour to conceal by giving the white ground on which they apply it a shade of blue. It is with this varnish that the dial plates of clocks are covered after having been painted white.

Solution in  
oil of tur-  
pentine.

When copal is treated with oil of turpentine in close vessels, the vapour being prevented from escaping, exerts a greater pressure, and the heat rises above the boiling point. This additional heat is said to enable the oil to dissolve the copal. The solution, mixed with a little poppy oil, forms a varnish which is distinguished from the *vernix martin* merely in having a very slight tinge of brown \*.

Solution by  
means of  
ammonia,

The method of dissolving copal in oil of turpentine, published by Mr Sheldrake, seems to depend upon the same principle with the last solution. On two ounces of copal, broken into small pieces, is poured a mixture of four ounces of ammonia with a pint of oil of turpentine. The whole is kept boiling very gently, so that

---

\* Dr Black's *Lectures*, ii. 359.

the bubbles may be counted as they rise. If the heat be allowed to diminish, or if it be raised too high, the process stops, and cannot be again resumed. The mat-  
trass, in which the mixture is boiled, is stopped with a cork, secured in its place by a brass wire, and perforated by a pin. When the copal is nearly dissolved, the process is stopped, and the whole allowed to cool before uncorking the mat-  
trass. This varnish has a deep colour; but when spread thin and allowed to dry, it becomes colourless. Its defect is the difficulty with which it dries. This defect Mr Sheldrake remedies by throwing the solution into its own weight of nut oil, rendered drying by white lead, and agitating till the turpentine is separated.

Chap. I.

To dissolve copal in alcohol, Mr Sheldrake dissolves half an ounce of camphor in a pint of that liquid, and pours the solution on four ounces of copal. The mat-  
trass is placed in a sand bath, and the process is conducted exactly as the one last described. The solution thus formed contains a great deal of copal, and forms a varnish which is perfectly colourless; but considerable heat is necessary to drive off the camphor.

And camphor.

Mr Sheldrake has lately favoured the public with another and easier method of dissolving copal. This method is as follows:

"Provide a strong vessel made of tin or other metal; it should be shaped like a wine bottle, and capable of holding two quarts; it will be convenient to have a handle strongly rivetted to the neck; the neck should be long and have a cork fitted to the mouth, but a notch or small hole should be made in the cork, that, when the spirit is expanded by heat, a small portion

Sheldrake's process.



Book IV.

may force its way through the hole, and thus prevent the vessel from bursting.

"Dissolve half an ounce of camphor in a quart of spirit of turpentine, and put it into the vessel; take a piece of copal the size of a large walnut, reduce it to coarse powder or very small pieces; put them into the tin bottle, fasten the cork down with a wire, and set it as quick as possible upon a fire so brisk as to make the spirit boil almost immediately; then keep it boiling very gently for about an hour, when so much of the copal will be dissolved as will make a very good varnish; or, if the operation has been properly begun, but enough of copal has not been dissolved, it may be again put on the fire, and by boiling it slowly for a longer time, it may be at last brought to the consistence desired \*."

Demmen-  
ic's pro-  
cess.

Van Mons relates another process much simpler than any of the above, which he says was taught him by Mr Demmenic, a Dutch artist. It consists in exposing copal to the action of the steam of alcohol. A long necked matrass is filled one-fourth full of strong alcohol, and a piece of copal is suspended above the surface of the liquid at some little distance; the top of the matrass is covered with a condensator; the alcohol is kept boiling: the copal softens, and drops down into the alcohol like oil. When these drops no longer dissolve, the process must be stopped. The solution thus obtained is perfectly colourless. Copal may be dissolved in oil of turpentine by the same process †.

The following method of making copal varnish has

\* *Nicholsen's Jour.* ix. 157.

† *Jour. de Chim.* iii. 218.

been recommended by Professor Lenormand. Drop  
 upon the pieces of copal pure essential oil of rosemary.  
 Those pieces that are softened by the oil are fit for the  
 purpose, the others not. Reduce them to a fine pow-  
 der, put this powder into a glass vessel not thicker than  
 a finger breadth, pour oil of rosemary over it, and stir  
 it about with a glass rod. In a short time the whole  
 is converted into a very thick liquid. Pour alcohol on  
 this liquid by little at a time, incorporating it, by gently  
 agitating the vessel, till it is of the requisite thinness for  
 use \*.

Chap. I.

Lenormand's process.

12. *Lac*.—This is a substance deposited on different  
 species of trees in the East Indies, by an insect called  
*thremes lacca*, constituting a kind of comb or nidus. It  
 has been imported into Europe, and extensively used  
 from time immemorial; but it is only of late years  
 that correct information concerning it has been obtain-  
 ed. For what relates to the natural history of the in-  
 sect, and the mode of forming the lac, we are indebted  
 to Mr Ker, †, Mr Saunders ‡, and Dr Roxburgh §.  
 Though very often employed in the arts, it was neglect-  
 ed by chemists. Geoffroy junior, indeed, published a  
 dissertation on it, but it contains few chemical experi-  
 ments. He merely subjected it to distillation, and ob-  
 tained products which he thought similar to those given  
 by wax in the same circumstances ||. This led him to  
 consider it as a species of wax, an opinion followed by

History.

\* Nicholson's Jour. xxiiv. 67.

† Phil. Trans. 1781, p. 376.

‡ Ibid. 1789, p. 107.

§ Ibid. 1791, p. 228.

|| Mem. Par. 1714, p. 121; and Martine's translation of the *Memoires*  
 of the French Academy, v. 4.



Book IV. Neumann \*; but Junker †, and most of the subsequent chemical writers, place it among the resins. Mr Hatchett has lately examined it with his usual address, and ascertained its composition and properties ‡. To him we are indebted for almost every thing which we know respecting its chemical nature.

Varieties. There are various kinds of lac distinguished in commerce. *Stick lac* is the substance in its natural state, encrusting small twigs. When broken off and boiled in water it loses its red colour, and is called *red lac*. When melted and reduced to the state of thin crust, it is called *shell lac*. *Stick lac* is of a deep red colour, and yields to water a substance which is used as a red dye. The other two varieties are brown.

Properties. Water dissolves the greatest part of the colouring matter of lac, which varies from 15 to  $\frac{1}{2}$  per cent. Alcohol dissolves the greatest part of the resin, which constitutes the chief ingredient in the composition of lac. Ether acts more feebly. Sulphuric acid dissolves and gradually chars lac; nitric acid dissolves, and then produces the same changes on it as on other resinous bodies. Muriatic and acetic acids likewise act as solvents. A solution of borax in water readily dissolves lac. The best proportions are 20 grains of borax, 100 grains of lac, and four ounces of water. This solution, mixed with lamp black, constitutes Indian ink; and may indeed be employed for many of the purposes of varnish. The fixed alkalies readily dissolve lac, but not the volatile. When placed on a hot iron it

\* Chemistry, p. 334.

† *Conspectus Chemia*, ii. 70.

‡ Analytical Experiments on Lac, *Phil. Trans.* 1804.

melts, and emits a thick smoke with an odour rather pleasant, leaving a spongy coal. When distilled, it yields water slightly acidulous, and a thick butyraceous oil. The gases emitted are a mixture of carbonic acid and carbureted hydrogen. Stick lac yields also some carbonate of ammonia; but the other two varieties none. The following Table exhibits the constituents of the different varieties of lac, according to the analysis of Mr Hatchett.

	Stick Lac.	Seed Lac.	Shell Lac.
Resin	68	88.5	90.9
Colouring matter	10	2.5	0.5
Wax	6	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5		
Loss	4.0	2.5	1.8
	100	100	100

Constitu-  
ents.

The resin is less brittle than those bodies usually are. The colouring matter possesses the properties of extractive; the wax is analogous to myrtle wax, and the gluten closely resembles the gluten of wheat\*.

The uses to which lac is applied in India are very numerous. In Europe it forms the basis of sealing wax; which is made by melting lac with different proportions of turpentine and some colouring matter, as ivory black, for black sealing wax; vermilion for red, &c. It constitutes also the basis of many varnishes

Uses.

\* Hatchett, *Phil. Trans.* 1804.

Book IV. and lackers. This last name indeed is derived from the word *lac* \*.

**Amber.** 13. *Amber*.—This substance is undoubtedly of vegetable origin; and though it differs from resins in some of its properties, yet it agrees with them in many others, that it may, without impropriety, be referred to them. For the chemical investigation of the properties of this substance, we are chiefly indebted to the labours of Hoffmann †, Bourdelin ‡, Stockard §, Neuform ¶, Heyer ||, and more lately it has occupied the attention of Mr Hatchett. The best account of amber varnish which I have seen is by Nils Nystro in the Stockholm Transactions for 1797 \*\*.

**Properties.** Amber is a brittle, light, hard substance, usually nearly transparent; sometimes nearly colourless, but commonly yellow or even deep brown. It has considerable lustre. Its specific gravity is 1.065. It is tasteless, and without smell, except when pounded and heated, when it emits a fragrant odour. When heated it softens; but, as far as is known, cannot be melted without losing some of its weight, and altering its ap-

---

\* A detailed account of the method of making several of these is given by Dr Lewis in his *Philosophical Commerce of the Arts*, p. 223.

† *Obs. Phys. Chém.* p. 60, and 198.

‡ *Sur le Succin. Mém. Par.* 1742, p. 192.

§ *Specimen. Chem. Med. Inaugur. de Succino in Genere et Speciatim de Succino Fossili Wisbelzenensi*, 1760. This tract contains a very copious set of experiments; which, however, do not always agree with those of other chemists. Wasserberg's Treatise on Amber is chiefly an abridgment of Stockard's.

|| *Chemische versuche mit Bernstein*, 1787.

\*\* I have seen the paper only through the medium of Crell's Journal; it is inserted in Crell's *Annals*, 1797, ii. 171. and 251.



pearance. In a strong heat it burns, leaving a small quantity of ashes, the nature of which has not yet been ascertained. Water has no action on it; but alcohol, by long digestion, dissolves about one-eighth of the amber, and forms a coloured solution, which when concentrated becomes milky when mixed with water. The precipitate possesses the properties of a resin. The residuum of the amber is not acted on by alcohol. Though amber be roasted before the action of the alcohol, the tincture is still formed. Hence we learn that the resinous part of amber is not expelled by a melting heat\*. When amber is treated with a boiling fixed alkali, it is almost completely dissolved, according to Hoffman, and the compound possesses the qualities of soap; for it is soluble in water and alcohol, and not thrown down by water. Mr Hatchett found that the alkalies act only partially on amber, extracting a yellow tincture. Probably this ingenious chemist did not continue the process long enough; for I have accidentally ascertained, that a weak solution of potash is capable of dissolving amber completely without the assistance of heat, provided it be allowed to act for a sufficient time. I had formed a weak solution of potash (I believe subcarbonate) as nearly as possible of the specific gravity of amber, and I had put into it some amber powder, to show the supposed currents of Count Rumford during the heat of the liquid. On examining the infusion about a month after, I found the amber all lying at the bottom of the phial. I added more alkali to restore the equilibrium. Some time after the

Action of  
alkalies,



Book IV. Amber was again at the bottom, and it was necessary to add more alkali. By this time the solution had acquired a yellow colour. I therefore explained the sinking of the amber, by supposing that the potash had dissolved a portion of it, and that this had altered the specific gravity of the solution. Not knowing at the time that any experiments had been made on the subject, I put aside the phial to ascertain the result. This was three years ago; and at present only two or three particles of the amber at most can be detected, the rest is dissolved completely.

Of acids. The weaker acids have no action on amber. Sulphuric acid converts it into a black resinous mass. Nitric acid acts upon it; when assisted by heat, nitrous gas is emitted. The amber is first converted into a light resinous substance, and at last dissolves completely. Heyer, who first made this experiment, could obtain neither oxalic nor acetic acid by the action of nitric acid on amber. That nitric acid is really capable of dissolving amber, has been lately verified by the experiments of Hatchett, who found it soluble with the same phenomena as resins in general.

Amber varnish. Neither fixed nor volatile oils have any action on amber unless it has been previously roasted or exposed to a melting heat. When thus treated, it combines with oils, and the solution forms *amber varnish*. The process recommended by Nystrom is this: Amber is to be spread on a flat bottomed iron pan, and placed on an equal coal fire till it melt; it is then to be withdrawn, covered with a plate of copper and iron, and allowed to cool. If the process be properly conducted, the amber will have lost half of its weight. If the fire be too strong, the amber will be scorched and rendered

useless. If it be too low, the amber will not melt, but be reduced to a brown crust, which answers well enough for a varnish, provided it be exposed to heat till it is reduced to one-half of the original weight. One part of this roasted amber is to be mixed with three parts of linseed oil (rendered drying by litharge and white vitriol), and the mixture exposed to a gentle heat till the amber is dissolved; it is then to be withdrawn from the fire, and when nearly cold four parts of oil of turpentine are to be added. The whole is then allowed to settle, and the clear portion is passed through a linen cloth.

When amber is distilled, there comes over carburated hydrogen and carbonic acid gas, an acidulous water, then an oil, at first thin and transparent, but becoming gradually darker and thicker. Towards the end of the process the succinic acid sublimes. From the observations of Vogel, it appears that a portion of the yellow matter which is obtained by this distillation possesses the properties of wax very nearly.

14. *Resin from bitumen.*—Mr Hatchett ascertained, that when asphalt, mineral caoutchouc, and other similar bodies, are digested a sufficient time in nitric acid, they furnish a considerable portion of a brown substance, which possesses many of the properties of resins. Kilkenny coal, and every other variety of coal which contains no bitumen, is converted by nitric acid into artificial tannin, but yields no resin; while common coal furnishes both. Thus it appears that bitumen, when treated with nitric acid, has the property of yielding a species of resin.

Resin from  
bitumen.

## Book IV.

## Properties.

This substance has a pale brown colour like that of Spanish snuff; its internal fracture is dark brown, and it has a resinous lustre. When heated it does not readily melt; but when inflamed emits a resinous odour, mixed with that of fat oils, and leaves a coal much more bulky than the original substance. Alcohol dissolves it. Water throws down a part from the solution; but a portion remains undissolved, which acts on reagents like *extractive*. The taste is bitter. Hence this substance appears to be intermediate between *extractive* and resin. When digested with nitric acid it is readily converted into artificial tannin; and when digested with sulphuric acid it is converted into charcoal\*.

I have now enumerated the most remarkable of the resinous bodies with which we are acquainted. There are indeed many of the substances employed in medicine, which undoubtedly contain resins; for example, *aloes*, *jalap*, *snake root*, *arnica*, &c.; but as these have not yet been chemically examined, it would be in vain to dwell upon them.

---

\* Hatchett's Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.



## SECT. XXIV.

## OF GUAIACUM.

THIS substance is obtained from the *guaiacum officinale*, Origin. a tree which is a native of the West Indies, and yields a very hard heavy wood. The resin exudes spontaneously, and is also driven out artificially by heating one end of the wood in billets previously bored longitudinally; the melted resin runs out at the extremity farthest from the fire. This substance has been used in medicine for a considerable time, having been originally recommended in venereal diseases. Nothing is known concerning its original introduction into Europe.

It was considered by chemists as a resin, till Mr Hatchett observed, that when treated with nitric acid it yielded products very different from those of resinous bodies\*. This induced Mr William Brande to examine its chemical properties† in detail †. To his valuable paper we are indebted for almost all the accurate information which we possess respecting its chemical nature.

1. Guaiacum is a solid substance, resembling a resin Properties. in appearance. Its colour differs considerably, being

\* Second Series of Experiments on Artificial Tamin, *Phil. Trans.* 1803.

† Chemical Experiments on Guaiacum, *Phil. Trans.* 1806, and *Phil. Mag.* xiv. 103.

Vol. V.



Book IV.

partly brownish, partly reddish, and partly greenish; and it always becomes green when left exposed to the light in the open air\*. It has a certain degree of transparency, and breaks with a vitreous fracture. When pounded it emits a pleasant balsamic smell, but has scarcely any taste, although when swallowed it excites a burning sensation in the throat. When heated it melts, and diffuses at the same time a pretty strong fragrant odour. Its specific gravity is 1.2289†.

Action of  
water,

2. When guaiacum is digested in water a portion of it is dissolved, the water acquiring a greenish brown colour and a sweetish taste. The liquid, when evaporated, leaves a brown substance, which possesses the properties of *extractive*; being soluble in hot water and alcohol, but scarcely in sulphuric ether, and forming precipitates with muriates of alumina, tin, and silver. This extractive amounts to about nine parts in the hundred of guaiacum‡.

## Alcohol.

3. Alcohol dissolves guaiacum with facility, and forms a deep brown coloured solution. Water renders this solution milky by separating the resin. Muriatic acid throws down the guaiacum of an ash grey, and sulphuric acid of a pale green colour. Acetic acid and the alkalies occasion no precipitate. Liquid oxymuriatic acid throws it down of a fine pale blue, which does not change when dried. Diluted nitric acid occasions no change at first; but after some hours the liquid becomes green, then blue, and at last brown, and at that period a brown coloured precipitate falls down

---

\* Wollaston, Nicholson's *Jour.* viii. 294.

† Brande, *Phil. Mag.* xiv. 105.

‡ Id. *Ibid.*

If water be mixed with the liquid when it has assumed a green or a blue colour, green and blue precipitates may be respectively obtained \*.

Chap. I.

3. Sulphuric ether does not act so powerfully on *Guaiaecum* as alcohol. The solution obtained by means of it, exhibits the same properties when treated with reagents as that in alcohol †.

Ether,

4. The alkaline solutions, both pure and in the state of carbonates, dissolve *guaiaecum* with facility. Two ounces of a saturated solution of potash dissolved about 65 grains of *guaiaecum*; the same quantity of ammonia only 25 grains; or *guaiaecum* dissolves in about 15 parts of potash and 38 parts of ammonia. Nitric acid threw down from these solutions a brown precipitate, similar to what is obtained when the alcoholic solution is mixed with the same acid. Muriatic acid and diluted sulphuric acid throw down a flesh-coloured curdy precipitate, which in its properties approaches the nature of extractive ‡.

Alkalies

5. Most of the acids act upon *guaiaecum* with considerable energy.

Action of acids.

Sulphuric acid dissolves it, and forms a deep red liquid, which deposits while fresh a lilac-coloured precipitate when mixed with water. When heat is applied the *guaiaecum* is charred.

Nitric acid dissolves *guaiaecum* completely without the assistance of heat, and with a strong effervescence. When the solution is evaporated, it yields a very large

\* Brande, *Phil. Mag.* xxv. 106.

† *Ibid.*

‡ *Ibid.* p. 109.

# INGREDIENTS OF PLANTS.

IV. quantity of oxalic acid \*. No artificial tannin appears to be formed, but rather a substance possessing the properties of extractive. Diluted nitric acid converts guaiacum into a brown substance, similar to the precipitate obtained by nitric acid from the alcoholic solution of guaiacum. This brown matter possesses the properties of a resin †.

Muriatic acid acts but slightly, as the guaiacum soon melts into a blackish mass, which is not acted upon ‡.

Distillation.

6. When guaiacum is distilled, 100 parts of it yielded to Mr Brande the following products :

Acidulous water.....	5.5
Thick brown oil.....	24.5
Thin empyreumatic oil.....	30.0
Charcoal.....	30.5
Gases, consisting of carbonic acid and carbureted hydrogen .....	9.5
	<hr/> 100.0

The coal when incinerated left three grains of lime, but no alkaline substance §.

7. Such are the properties of guaiacum, as far as they have been hitherto ascertained. From the preceding detail, it is obvious that guaiacum in many respects coincides with the resins; but it differs from them in three particulars so remarkable, that we cannot avoid considering it as a distinct substance.

Peculiar properties.

The first of these is the great quantity of charcoal which it leaves when distilled in close vessels. This

\* Hatchett, Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.  
 † Brande, *Phil. Mag.* xiv. p. 107.  
 ‡ *Ibid.*  
 § *Ibid.*



Mr Brande found to amount to above 30 *per cent.*; while the resins, in like circumstances, hardly ever leave more than 15 *per cent.* of charcoal, and often not nearly so much. It is possible, however, and indeed not improbable, that this difference is to be ascribed to the different degrees of heat employed.

The second peculiarity is the action of nitric acid on guaiacum. This acid does not dissolve the resins without the assistance of heat, but converts them into a brown brittle mass; whereas it dissolves guaiacum completely. The action of this acid on the resins terminates in the formation of artificial tannin, whereas its action on guaiacum terminates in the formation of oxalic acid. This striking difference is alone sufficient to warrant a separation of guaiacum from the resins.

The third peculiarity is the remarkable suite of changes of colour which guaiacum undergoes when its solutions are treated with nitric and oxymuriatic acids. Dr Wollaston first observed that guaiacum becomes green when exposed to light, provided air have access to it; and that the colour is again removed by the application of heat\*. Hence it is probable that oxygen occasions the change. This opinion is much strengthened by the experiments of Mr Brande. When guaiacum was put in contact with oxygen gas, it became green sooner than in the open air. When put into oxymuriatic gas it became first green, then blue, and lastly brown; and ammonia, when left in contact with it, restored again its green colour. In like manner, by treating the alcoholic solution of guaiacum

Forms ox-  
ides.

\* Nicholson's Jour. viii, 295.



Book IV.

with nitric acid, green, blue, and brown precipitates obtained, according to the length of time that the is allowed to act upon it. - These facts give considerable plausibility to the opinion of Mr Brande, that changes of colour are owing to the combinations of oxygen with the guaiacum; that the green contains least, and the brown the most oxygen, while the is intermediate \*. Thus guaiacum, in its changing colour, bears some resemblance to indigo. Mr Brande has remarked a coincidence also between guaiacum and the green resin of the leaves of plants.

---

## SECT. XXV.

### OF BALSAMS.

THE term *balsam* or *balm* was originally confined to a thick fragrant juice obtained from the *amyris G. densa*, and afterwards applied by chemists to all substances which possessed the same degree of consistency and a strong smell, whether natural or artificial. Bucquet restricted the term to those resinous-like substances which yield benzoic acid when heated. The new meaning of the word, which has been adopted by chemists in general, has introduced into the class of balsams several substances which were formerly considered as resins. The word *balsam* originally im-

---

\* Brande, *Phil. Mag.* xxv. 107.

a substance possessing a certain degree of fluidity ; but now there are two classes of balsams ; the one fluid, and the other solid and brittle.

Chap. I.

A balsam, then, is a substance which possesses the general properties of a resin ; but which, when heated or digested in acids, yields a portion of benzoic acid. Chemists, in general, have considered them as combinations of a resin with benzoic acid ; but Mr Hatchett has made it probable, that the acid is formed at the time of its separation \*.

Definition.

They are insoluble in water ; but when boiled in that liquid often give out a portion of benzoic acid. Alcohol and ether dissolve them readily. The strong acids likewise dissolve them ; and during the solution a portion of benzoic acid is separated. Nitric acid, in some cases, evolves likewise traces of prussic acid. The alkalies act upon them nearly as on the resins. They may be divided into two classes ; namely, *liquid* and *solid* balsams.

Properties.

Division.

### I. LIQUID BALSAMS.

The liquid balsams at present known are five in number ; namely,

- |                |            |
|----------------|------------|
| 1. Opobalsamum | 4. Peru    |
| 2. Copaiva     | 5. Styrax. |
| 3. Tolu        |            |

1. *Opobalsamum* or *balm of Gilead*.—This balsam is obtained from the *amyris Gileadensis*, a tree which grows in Arabia, especially near Mecca. It is so much valued by the Turks that it is seldom or never import-

Opobalsamum.

\* Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

Book IV.

ed into Europe. We are of course ignorant of its composition. It is said to be at first turbid and white, and of a strong aromatic smell, and bitter, acrid, astringent taste; but by keeping, it becomes limpid and thin, and its colour changes first to green, then to yellow, and at last it assumes the colour of honey, and the consistence of turpentine\*.

Copaiva

2. *Copaiva*.—This balsam is obtained from the *copaifera officinalis*; a tree which grows in South America, and some of the West Indian islands. It exudes from incisions made in the trunk of the tree. The juice thus obtained is transparent, of a yellowish colour, an agreeable smell, a pungent taste, at first of the consistence of oil, but it gradually becomes as thick as honey. Its specific gravity is 0.950†. When mixed

Yields oil

with water and distilled, there comes over with the water a very large portion of volatile oil. Lewis obtained half the original weight of this oil‡. Schonberg, from eight ounces of copaiva, obtained 3½ of oil by this process§. It was colourless, very limpid, of the specific gravity 0.000; had the taste and smell of copaiva, but rather stronger. It dissolved in eight parts of alcohol; but the copaiva itself is a good deal more soluble||. The oil ceases to come over before all the water has passed into the receiver. The residuum,

and resin;

of course, consists of two substances; namely, the watery portion, and a greyish yellow substance, lying at the bottom of the vessel, which, on exposure to the air, dries, and becomes brittle and transparent. When

\* This is the account of Professor Alpinus, as quoted by Lewis, Neumann's *Chem.* p. 284.

† Schonberg, Gehlen's *Jour.* vi. 494.

‡ Neumann's *Chem.* p. 285.

§ Gehlen's *Jour.* vi. 494.

|| Schonberg, *Ibid.*

heated it melts, and possesses the characters of a resin. When distilled it yielded a yellowish thick oil, some acidulous water, and a gas; one-sixth of which was carbonic acid, and the remainder seemed to possess the characters of olefiant gas\*. From these facts, which have been long known, it was concluded, that copaiva is a compound of a resin and a volatile oil, which passes over at a heat inferior to that of boiling water; but the experiments of Schonberg have rendered it much more probable, that the balsam is decomposed when distilled along with water, and that both the oil and resin are new products.

Chap. I.

But is decomposed.

When distilled on a water bath, nothing comes over but a few drops of water, and one or two drops of oil †. If the vessel be kept at a temperature between 234° and 257°, scarcely any thing more is obtained than when the distillation is conducted over a water bath. At the temperature of 504° the balsam begins to boil gently, a gas is extricated, and drops begin to pass more rapidly into the receiver. At 550° it boils briskly, and the distillation goes on rapidly. There passes into the receiver a limpid yellowish oil, occasionally mixed with a drop or two of water. As the distillation proceeds the oil becomes more and more yellow. At this period the balsam is as liquid as water, and boils without any frothing or swelling. After this period the oil becomes yellow, and then brownish red; but still continues pretty thin. The first oil obtained by Schonberg from four ounces of copaiva, by this process, was 3  $\frac{1}{8}$  ounces. The water had a sour taste, and reddened.

Distillation.

\* Schonberg, Gehlen's Jour. vi. p. 497.

† Id. Ibid. p. 495.



**Book IV.** ed litmus paper. The gas amounted to 81 on measures;  $\frac{1}{7}$ th of it was carbonic acid, the rest resembled olefiant gas\*.

**Action of nitric acid,** Nitric acid acts upon this balsam with considerable energy. When one part of the balsam is mixed with four parts of nitric acid and two parts of water, heated, a yellowish solution is formed, similar to original balsam, but darker. When distilled, it comes over with the liquid that passes into the receiver an apple-green oil, which lines the helm of retort. The nature of the residue was not examined. Doubtless it would have been found to contain artificial tannin, provided a sufficient quantity of acid was employed†.

**Similar to turpentine.** When treated with sulphuric acid, it yields a portion of artificial tannin‡.

Whether this balsam yields benzoic acid has been ascertained. Its properties are rather against probability of its doing so. Indeed it bears a striking resemblance to turpentine in many respects; and our balsam along with it, to constitute a class of bodies intermediate between volatile oils and resins, to which name of *terpentines* might be given.

**Balsam of tolu.** 3. *Balsam of Tolu.*—This substance is obtained from the *toluifera balsamum*, a tree which grows in South America. The balsam flows from incisions made in the bark. It comes to Europe in small gourd shells. It is of a reddish brown colour and considerable quantity.

\* Schouberg, Gehlen's *Jour.* vi. 495.

† *Id.* *Ibid.* p. 499.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, *Trans.* 1806.

sistence ; and when exposed to the air, it becomes solid and brittle. Its smell is fragrant, and continues so even after the balsam has become thick by age. When distilled with water, it yields very little volatile oil, but impregnates the water strongly with its taste and smell. A quantity of benzoic acid sublimes, if the distillation be continued \*.

Mr Hatchett found it soluble in the alkalies, like the rest of the balsams. When he dissolved it in the smallest possible quantity of lixivium of potash, it completely loses its own odour, and assumes a most fragrant smell, somewhat resembling that of the clove pink. "This smell," Mr Hatchett observes, "is not fugitive, for it is still retained by a solution which was prepared in June, and has remained in an open glass during four months."

Action of  
alkalies,

When digested in sulphuric acid, a considerable quantity of pure benzoic acid sublimes. When the solution of it in this acid is evaporated to dryness, and the residue treated with alcohol, a portion of artificial tannin is obtained ; the residual charcoal amounts to 0.54 of the original balsam †.

And acids

Mr Hatchett found that it dissolved in nitric acid with nearly the same phenomena as the resins ; but it assumed the odour of bitter almonds, which leads him to suspect the formation of prussic acid. During the solution in nitric acid, a portion of benzoic acid su-

---

\* Lewis, Neumann's *Chem.* p. 285.

† Hatchett, Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

Book IV.

blimes. By repeated digestions it is converted into artificial tannin\*.

Balsam of  
Peru.

4. *Balsam of Peru*.—This substance is obtained from the *myroxylon peruiferum*, which grows in the warm parts of South America. The tree is full of resin, and the balsam is obtained by boiling the twigs in water. It has the consistency of honey, a brown colour, an agreeable smell, and a hot acrid taste. When boiled with water for some time, the liquid separated by the filter reddens vegetable blues, and deposits crystals of benzoic acid on cooling. The water contains no other substance†. When distilled with water, it yields a very small quantity of reddish limpid oil. Hoffmann obtained only one part of oil from 16 of balsam‡. Lichtenberg mixed two ounces of balsam with eight of water, and distilled. The first two ounces of water came over colourless, and had only a slight odour of the balsam. The next three were milky, smelt strongly of the balsam, and at the bottom of the receiver were some drops of colourless oil. The next 1½ ounces were similar, but contained more oil. Between 50 and 60 grains of benzoic acid had sublimed into the neck of the retort. By increasing the heat 3¼ drachms of yellow oil came over, and a quantity of benzoic acid. A black shining coal remained in the retort§.

Action of  
heat.

When this balsam is exposed to the heat of a water bath, only a drop or two of water and a few drops of

\* Hatchett, Second Series of Experiments on Artificial Tannin, *Philos. Trans.* 1806.

† Lichtenberg, *Gehlen's Jour.* vi. 489.

‡ *Observ. Phys. Chym. Select.* p. 71.

§ *Gehlen's Jour.* vi. 485.

can be obtained\*. When placed in a sand bath, exposed to a temperature gradually raised, nothing comes over till the balsam is heated to  $300^{\circ}$ , when a portion of benzoic acid sublimes; and at  $324^{\circ}$ , drops of water and oil began to come over. At  $550^{\circ}$  the balsam begins to boil, and some gas is disengaged. At  $617^{\circ}$  the oil (mixed with a little water) comes over very fast. At  $617^{\circ}$  it comes over still more rapidly. Lichtenberg, to whom we owe these experiments, kept two ounces of balsam at that temperature for two days, and obtained two ounces of a yellowish oil, and a crystallized mass of benzoic acid, which, together with the water, weighed  $6\frac{1}{2}$  drachms. The gas obtained amounted to 56 ounce measures; of these, 38 were benzoic acid. The rest burnt like olefiant gas. By raising the heat a brownish oil came over, and at last a black oil of the consistence of pitch, and 49 ounce measures of gas were extricated. Of these, six were benzoic acid; the residue burnt with a bluish white gas†.

A saturated solution of carbonate of soda forms with the balsam a thick mass. When diluted with water and heated, a portion is dissolved. The solution, when mixed with sulphuric acid, deposits crystals of benzoic acid. One part of the balsam, treated with one part of potash dissolved in four parts of water, forms an opaque solution, which gradually separated into two portions: the uppermost, a clear oil with some very flakes at its lower surface; the undermost, a dark brownish red opaque solution. This last solution,

Of alkalies.

\* Lichtenberg, Gehlen's *Jour.* vi. 485.

† *Ibid.* p. 487.



Book IV.

when saturated with sulphuric acid, lets fall a resin like substance, dissolved by boiling, while benzoic crystallized \*.

Urtica.

Nitric acid acts upon the balsam with energy, gives it an orange yellow colour when assisted by heat. When distilled with a sufficient quantity of this diluted, the liquid in the receiver smells of bitter almonds. When supersaturated with carbonate of potash and mixed with a solution of iron, a precipitate is formed which, when treated with muriatic acid, leaves prussic blue, and indicates the presence of prussic acid. During the distillation benzoic acid sublimes. The residue in the retort has a crystalline appearance, is yellow, dissolves sparingly in boiling water, and precipitates on cooling in the state of a yellow powder. Such was the result of Lichtenberg's trials. Mr Hatchett observed that the residue possessed the properties of artificial tannin.

When this balsam is treated with sulphuric acid, artificial tannin is also formed, and the residual char amounts to not less than 0.64 of the original weight of the balsam †.

Styrac.

5. *Styracis*.—This is a semifluid juice, said to be obtained from the *liquidambar styraciflua*, a tree which grows in Virginia, Mexico, and some other parts of America ‡. It is prepared, according to Mr Petri, in the island Cebros in the Red Sea, from the bark

\* Lichtenberg, Gehlen's Jour. vi. 487.

† Gehlen's Jour. vi.

‡ Hatchett, Third Series of Experiments on Artificial Tannin, Trans. 1806.

§ Lewis, Neuman's Chemistry, p. 292.

of a tree called *rosa mallos* by the natives, and considered by botanists as the same with the American species. The bark of this tree is boiled in salt water to the consistence of bird-lime, and then put into casks\*. Honillon la Grange has published an account of its properties†. Its colour is greenish, and its taste aromatic, and its smell agreeable. It is easily volatilized by heat. When treated with water, benzoic acid is dissolved. It is totally soluble in alcohol except the impurities. When exposed to the air it becomes harder, and absorbs oxygen. When distilled, it yields an acidulous water, having the odour of benzoic acid, a limpid colourless hot oil, a solid coloured oil, benzoic acid, and a mixture of carbonic acid and carbureted hydrogen. The charcoal is light and contains some oil.

## II. SOLID BALSAMS.

The solid balsams at present known are only three in number; namely,

1. Benzoin
2. Storax
3. Dragon's blood

1. *Benzoin*.—This substance is the produce of the *styrax benzoe*, a tree which grows in Sumatra, &c. and which has been described by Dr Dryander‡. Benzoin is obtained from this tree by incision; a tree yielding three or four pounds. It is a solid brittle substance, sometimes in the form of yellowish white tears joined

Benzoin.

\* *Phil. Trans.* 1708, vol. xvi. p. 44.

† *Ann. de Chim.* xvi. 203.

‡ *Phil. Trans.* 1787, p. 307.

# INGREDIENTS OF PLANTS.

Book IV.

together by a brown substance, and sometimes in the form of a brown substance not unlike common resin. It has a very agreeable smell, which is increased by heating the benzoin. It has little taste. Its specific gravity is 1.092. This substance has been used in medicine for ages, and various processes have been pointed out by chemists for extracting benzoic acid from it; but the only person who has examined its properties in detail is Mr William Brande\*.

Cold water has very little effect on benzoin, but boiling water takes up a portion of benzoic acid.

Action of alcohol,

Alcohol dissolves it when assisted by a gentle heat, and forms a deep yellow solution inclining to reddish brown. When this solution is diluted with water, the benzoin precipitates in the form of a white powder. It is precipitated also by muriatic and acetic acids, but not by the alkalies. A few drops of sulphuric acid likewise precipitate the benzoin; but an additional quantity redissolves it, and forms a liquid of the colour of port wine. When equal quantities of the alcoholic solution of benzoin and sulphuric acid are mixed, a dark pink precipitate falls. The liquid assumes a pink colour which becomes lilac when diluted with water. Nitric acid occasions a strong effervescence, and forms a dark red fluid with the alcoholic solution, but throws down no precipitate†.

Ether,

Ether dissolves benzoin with facility, and the solution with reagents exhibits the same phenomena as the alcoholic ‡.

Acids,

Nitric acid acts with violence on benzoin, and

\* Nicholson's Jour. x. 82.

† Brande, Ibid.

‡

verts it into an orange-coloured mass. When assisted by heat the acid dissolves the benzoin; and as the solution cools, crystals of benzoic acid gradually separate. Mr Hatchett ascertained that by this process a quantity of artificial tannin is formed.

Sulphuric acid dissolves benzoin, while benzoic acid (as Hatchett discovered) sublimes; the solution is at first a deep red. By continuing the digestion, a portion of artificial tannin is formed, and the charcoal evolved amounts to 0.48 of the benzoin dissolved \*.

Acetic acid dissolves benzoin without the assistance of heat. When heat is applied, the solution, as it cools, becomes turbid; owing to the separation of benzoic acid †.

Benzoin is dissolved by a boiling lixivium of the fixed alkalies; a dark brown solution is formed, which becomes turbid after some days exposure to the air. Ammonia likewise dissolves benzoin sparingly ‡.

When Mr Brande exposed 100 grains of benzoin in a retort to a heat gradually raised to redness, the products were,

Benzoic acid.....	9.0
Acidulous water.....	5.5
Butyraceous and empyreumatic oil.....	60.0
Charcoal .....	22.0
Carbureted hydrogen and carbonic acid	3.5

---

100.0

2. *Storax*.—This is the most fragrant of all the bal-

---

\* Hatchett, Third Series of Experiments on Artificial Tannin.

† Brande, Nicholson's *Jour.* 1. 26.

‡ Ibid. p. 26.



Book IV.

sams, and is obtained from the *styrax officinalis*, a tree which grows in the Levant, and it is said also in Italy. Sometimes it is in the state of red tears; and this is said to be the state in which it is obtained from the tree. But common storax is in large cakes; brittle, but soft to the touch, and of a reddish brown colour. This is more fragrant than the other sort, though it contains a considerable mixture of saw-dust. It dissolves in alcohol. When distilled with alcohol or with water, scarcely any oil is obtained. When distilled by the naked fire, it seems, from the experiments of Neumann, to yield the same products as benzoin\*.

Dragon's blood.

3. *Dragon's blood*.—This is a brittle substance of a dark red colour, which comes from the East Indies. There are two sorts of it; one in small oval drops or tears of a fine deep red, which becomes crimson when the tears are reduced to powder; the other is in larger masses, some of which are pale red, and others dark. It is probably obtained from different kinds of trees; the *calamus draco* is said to furnish most of what comes from India. The *dracæna draco* and the *pterocarpus draco* are also said to furnish it.

Properties.

Dragon's blood is brittle and tasteless, and has no sensible smell. Water does not act upon it, but alcohol dissolves the greatest part, leaving a whitish substance, partially acted upon by water. The solution has a fine deep red colour, which stains marble, and the stain penetrates the deeper the hotter the marble is. It dissolves also in oils, and gives them a deep red colour also. When heated it melts, catches flame, and

\* Neumann's *Chem.* p. 290.† Lewis, *Ibid.* p. 299.

emits an acid fume similar to that of benzoic acid \*. When digested with lime, a portion of it becomes soluble in water, and it acquires a balsamic odour. On adding muriatic acid to the solution, a red resinous substance is precipitated, and slight traces of benzoic acid only become perceptible †. Nitric acid acts upon it with energy, changes it to a deep yellow, a portion of benzoic acid is sublimed, and a brown mass remains soluble in water, and possessing the properties of artificial tannin ‡. When treated with sulphuric acid no perceptible portion of benzoic acid sublimes; but it is converted partly into artificial tannin, while a quantity of charcoal is evolved, amounting to 0.48 of the original dragon's blood employed §.

---

## SECT. XXVI.

### OF CAOUTCHOUC.

ABOUT the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe

History.

---

\* Lewis, Neumann's *Chem.* p. 299.

† Hatchett, Second Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

‡ Hatchett, *Ibid.*

§ Hatchett, Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

## Book IV.

were usually in the shape of bottles, birds, &c. The substance is very much used in rubbing out the mark made upon paper by a black lead pencil; and therefore in this country it is often called *Indian rubber*. Nothing was known of its production, except that it was obtained from a tree, till the French academicians went to South America in 1735 to measure a degree of the meridian. Mr de la Condamine sent an account of it to the French Academy in the year 1736. He told them, that there grew in the province of Esmeraldas, Brazil, a tree, called by the natives *Hbevé*; that from this tree there flowed a milky juice, which, when it was spissated, was *caoutchouc*. Don Pedro Maldonado, who accompanied the French academicians, found the same tree on the banks of the Maragnon; but he died soon after, and his papers were never published. Mr Freneau, after a very laborious search, discovered the same tree in Cayenne. His account of it was read to the French Academy in 1751.

Plants  
yielding it.

It is now known that there are at least two trees in South America from which *caoutchouc* may be obtained; the *hevea caoutchouc*, and the *jatropha elastica*; and it is exceedingly probable that it is extracted also from other species of *hevea* and *jatropha*. Several trees likewise which grow in the East Indies yield *caoutchouc*; the principal of these are, the *ficus indica*, the *artocarpus integrifolia*, and the *urceola elastica*; a plant discovered by Mr Howison, and first described and named by Dr Roxburgh\*.

When any of these plants is punctured, there exudes

---

\* *Asiatic Researches*, v. 167. London edition.

From it a milky juice, which, when exposed to the air, gradually lets fall a concrete substance, which is caoutchouc. Chap. I.

If oxymuriatic acid be poured into the milky juice, the caoutchouc precipitates immediately, and at the same time the acid loses its peculiar odour. This renders it probable that the formation of the caoutchouc is owing to its basis absorbing oxygen \*. If the milky juice be confined in a glass vessel containing common air, it gradually absorbs oxygen, and a pellicle of caoutchouc appears on its surface †.

Caoutchouc was no sooner known than it drew the attention of philosophers. Its singular properties promised that it would be exceedingly useful in the arts, provided any method could be fallen upon to mould it into the various instruments for which it seemed peculiarly adapted. Messrs de la Condamine and Fresneau had mentioned some of its properties; but Macquer was the first person who undertook to examine it with attention. His experiments were published in the *Mémoires* of the French Academy for the year 1769. They threw a good deal of light on the subject; but Macquer fell into some mistakes, which were pointed out by Mr Berniard, who published an admirable paper on caoutchouc in the 17th volume of the *Journal de Physique*. To this paper we are indebted for the greater number of facts at present known respecting caoutchouc. Mr Grostart and Mr Fourcroy having likewise added considerably to our knowledge of this singular sub-

---

\* Fourcroy, *Ann. de Chim.* xi. 259.

† *Ibid.*



#### INGREDIENTS OF PLANTS.

stance ; both of their treatises have been published in the 11th volume of the *Annales de Chimie*.

- a. Caoutchouc, when pure, is of a white colour \*, and without either taste or smell. The blackish colour of the caoutchouc of commerce is owing to the method employed in drying it after it has been spread upon moulds. The usual way is to spread a thin coat of the milky juice upon the mould, and then to dry it by exposing it to smoke ; afterwards another coat is spread on, which is dried in the same way. Thus the caoutchouc of commerce consists of numerous layers of pure caoutchouc alternating with as many layers of soot.

Caoutchouc is soft and pliable like leather. It is exceedingly elastic and adhesive ; so that it may be forcibly stretched out much beyond its usual length, and instantly recover its former bulk when the force is withdrawn. It cannot be broken without very considerable force. Its specific gravity is 0.9335 †.

icity  
g to  
t heat.

To that acute philosopher Mr Gough of Manchester, I am indebted for some very important experiments on the connexion between the temperature of caoutchouc and its elasticity. They have been since published in the second volume of the Manchester Memoirs, second series. It is necessary to premise, that Mr Gough has been blind from an infant, and that therefore his sense of touch is peculiarly delicate ; so much so, that he is an excellent botanist, and can distinguish plants with the utmost certainty by the feel : a power so extraordinary,

---

\* I have some pieces of it from the East Indies which had been allowed to inspissate in the open air. They are white, with a slight cast of yellow, and have very much the appearance and feel of white soap.

† Brisson.

that we who enjoy the advantage of sight can scarcely conceive how it can be acquired. Mr Gough's experiments are as follows: Chap. I.

Take a thong of this substance two or three inches long, and a few lines in breadth and thickness; put it in warm water till it becomes quite pliant: then, holding it merely extended between the two hands, bring the edge of it in contact with the lips, and observe the temperature (of the variations of which that part of the face is a very nice judge); then remove the thong a few lines from the lips, and stretch it forcibly, and bring it again in contact with the lips, and a very sensible increase of temperature will be perceived. Allow it to relax to its former state, and the temperature will be perceived immediately to sink. If we stretch the thong again, and then plunge it immediately into cold water, keeping it extended for a minute or more in the liquid, on letting go one end it will be found to have lost much of its contractile power; for it will not return to its former dimensions. But if we plunge it into warm water, or warm it by holding it for some time in the shut hand, it will begin to contract again, and soon return to its former figure and size. These experiments are of great importance, as they furnish a very palpable and convincing proof that ductility is owing to latent heat as well as fluidity. They afford a fine illustration of Dr Black's theory of latent heat. We see clearly that the elasticity of caoutchouc and the ductility of metals are different cases of one and the same thing.

Caoutchouc is not altered by exposure to the air; it is perfectly insoluble in water: but if boiled for some time its edges become somewhat transparent, owing un-

Book IV. doubtedly to the water carrying off the soot; and so soft, that when two of them are pressed and kept together for some time, they adhere as closely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please\*.

Action of alcohol. Caoutchouc is insoluble in alcohol. This property was discovered very early, and fully confirmed by the experiments of Mr Macquer. The alcohol, however, renders it colourless.

Ether. Caoutchouc is soluble in ether. This property was first pointed out by Macquer. Bernard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter was first cleared up by Mr Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility. Mr Grossart tried this experiment, and found it accurate†. It is evident from this that these chemists had employed ether in different states. The washing of ether has two effects. It deprives it of a little alcohol with which it is often impreg-

---

\* Grossart, *Ann. de Chim.* xi. 153. See a method of making caoutchouc tubes by means of this property, *Phil. Mag.* xii. 340.

† Grossart, *Ann. de Chim.* xi. 147.

rated, and it adds to it about one-tenth of water, which remains combined with it. Alcohol precipitates the caoutchouc from this solution.

Chap. I.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the *barvea*; but this method would be a great deal too expensive for common use.

Caoutchouc is soluble in volatile oils\*; but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted.

It is said by Berniard to be insoluble in alkalies; but I find upon trial that this is a mistake. I was led to make the experiment by an accident. I employed a caoutchouc bottle fitted with a stop-cock in the usual way for holding ammoniacal gas. The gas very soon disappeared, though the bottle was perfectly air-tight, as I learned by plunging it in water. This induced me to fill it repeatedly with gas. In a short time it became evident that the gas had been absorbed by the bottle itself. It became soft and then glutinous, and never recovered its elasticity. I then tried the alkalies in general, and found that they were all capable of producing the same changes on caoutchouc, and even of dissolving it, though in a very minute proportion.

Alkalies,

The acids act but feebly upon caoutchouc. Sulphuric acid, even after a very long digestion, only chars it

Acids,

\* Berniard.



**Book IV.** superficially. The proportion of charcoal obtained in Mr Hatchett's experiments was only *12 per cent.* and he could observe no traces of artificial tannin \*. But when heat is applied the caoutchouc is completely decomposed. When treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid is said to be formed †. Muriatic acid does not affect it ‡. The other acids have not been tried.

**Heat.** Fabroni has discovered, that rectified petroleum dissolves it, and leaves it unaltered when evaporated §.

When exposed to heat it readily melts; but it never afterwards recovers its properties, but continues always of the consistence of tar. It burns very readily with a bright flame, and diffuses a fetid odour. In those countries where it is produced, it is often used by way of candle.

When distilled it gives out ammonia ||. It is evident from this, and from the effect of sulphuric and nitric acid upon it, that it is composed of carbon, hydrogen, azote, and oxygen; but the manner in which they are combined is unknown.

**Plants containing it.**

It seems to exist in a great variety of plants; but is usually confounded with the other ingredients. It may be separated from resins by means of alcohol. It may be extracted from the different species of missletoe by water, with which, in the fluid state in which it exists in these plants, it readily combines. When mixed with gum or extractive, it may be separated by the following process: Digest a part of the plant containing it first in

---

\* Third Series of Experiments on Artificial Tannin, *Phil. Trans.* 1806.

† *Ann. de Chim.* xi. 232.

‡ Bernard.

§ *Ann. de Chim.* xi. 195.; and xii. 156.

|| *Ibid.* xi. 232.

water and then in alcohol, till all the substances soluble in these liquids are extracted. Dry the residuum, and digest it in five times its weight of rectified petroleum. Express the liquid part by squeezing the substance in a linen cloth. Let this liquid remain several days to settle, then decant off the clear liquid part, mix it with a third part of water and distil; the caoutchouc remains behind \*.

According to Bucholz, opium contains a considerable portion of caoutchouc †. That part of mastich which is insoluble in alcohol possesses the properties of caoutchouc, as has been formerly observed.

---

## SECT. XXVII.

### OF GUM RESINS.

**T**HIS class of vegetable substances has been long distinguished by physicians and apothecaries. It contains many active substances much employed in medicine; and they certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Unfortunately these substances have not yet attracted much of the attention of chemists. Their properties and constituents of course are but imperfectly ascertained. Of

---

\* Hermbstadt, *Med. and Phys. Jour.* iii. 372.

† *Ann. de Chim.* xxxiv. 133.

Book IV.

late, however, they have engaged the attention of M. Braconnet, who has recently published a very detailed examination of several of them, and has promised to examine in the same manner the whole of the class\*. They may, however, be distinguished by the following characters.

Properties.

They are usually opaque, or at least their transparency is inferior to that of the resins. They are always solid, and most commonly brittle, and have sometimes a fatty appearance.

When heated they do not melt as the resins do; neither are they so combustible. Heat, however, commonly softens them, and causes them to swell. They burn with a flame.

They have almost always a strong smell, which in several instances is alliaceous. Their taste also is often acrid, and always much stronger than that of the resins.

They are partially soluble in water; but the solution is always opaque, and usually milky.

Alcohol dissolves only a portion of them. The solution is transparent; but when diluted with water it becomes milky; yet no precipitate falls, nor is any thing obtained by filtering the solution.

Vinegar and wine likewise dissolve them partially; and the solution, like the aqueous, is opaque or milky.

According to Hermbstadt, they are insoluble in sulphuric ether.

The action of alkalies on them has been examined only by Mr Hatchett. All of them tried by that cele

---

\* *Ann. de Chim.* lxxviii. 19.

trated chemist dissolved readily in alkaline solutions when assisted by heat. We may therefore consider them as soluble in alkalies like resins.

Chap. I.

From the experiments of Mr Hatchett, we learn that the acids act on these bodies nearly as they do on the resins. Sulphuric acid dissolves them, and gradually converts them into artificial tannin and charcoal. The following are the quantities of charcoal obtained by this celebrated chemist from 100 grains of different gum resins digested in alcohol :

Ammoniac.....58	Myrrh.....40
Asafoetida.....51	Gamboge.....31
Olibanum.....44	

Nitric acid acts upon them with energy; converting them first into a brittle mass, and then, with the assistance of heat, dissolving them. By evaporating this solution, Mr Hatchett obtained, from ammoniac and asafoetida, a portion of artificial tannin; but he did not succeed in procuring it by the same means from olibanum, myrrh, and gamboge\*.

Their specific gravity is usually greater than that of the resins.

Their other properties still continue unknown. They all either exude spontaneously from plants, or are obtained by incisions. At first they seem to be in a liquid state; but they gradually harden when exposed to the air and weather.

They have been usually considered by chemists as composed of gum and resin; but their properties are not consistent with that supposition. They all contain

---

\* *Phil. Trans.* 1806.



Book IV.

a volatile oil, or a substance intermediate between an oil and resin. To this substance we are to ascribe the milky solution which they form with water. The other constituent, in most cases, bears a much closer resemblance to extractive than to gum. Perhaps, then, we will not err very far, if we consider the gum resins as composed of a gum or an extractive substance, and a body intermediate between oil and resin; to which last they owe their most peculiar properties.

The gum resins which have been hitherto applied to any useful purpose are the following :

**Galbanum.**

1. *Galbanum*. It is obtained from the *bubon galbanum*, a perennial plant, and a native of Africa. When this plant is cut across a little above the root, a milky juice flows out, which soon hardens and constitutes galbanum. It comes to this country from the Levant, in small pieces composed of tears, agglutinated together, of a yellowish or white colour. Its taste is acrid and bitter, and its smell peculiar. Water, vinegar, and wine, dissolve part of it, but the solution is milky. Alcohol dissolves about  $\frac{1}{3}$ ths. When distilled it yields about half its weight of volatile oil, which has at first a blue colour. Its specific gravity is 1.212\*.

**Ammoniac.**

2. *Ammoniac*.—This substance is brought from the East Indies. Nothing certain is known concerning the plant which yields it; though from analogy it has been suspected to be a species of *ferula*†. It is in small pie-

---

\* Brisson.

† Willdenow made the seeds vegetate which are observed in ammoniac. Of the plant produced he has formed a new genus under the name of *heracleum gummifera*. But as the roots of this plant were not observed to yield ammoniac, it is still doubtful how far it is the plant from which ammoniac is procured. See *Ann. de Chim.* lxi. 267.

ces agglutinated together, and has a yellowish white colour. Its smell is somewhat like that of galbanum, but more pleasant. Its taste is a nauseous sweet mixed with bitter. It does not melt. Water dissolves a portion of it; the solution is milky, but gradually lets fall a resinous portion. More than one-half is soluble in alcohol. This portion is a resin. Colour white, soft, and ductile. Melts when heated, and burns like a resin. When heated becomes harder, but not brittle. Nearly tasteless. Soluble in ether and in nitric acid. Precipitated from it in the form of an orange substance, partly resin, partly bitter. A portion remains, and gives the liquid a yellow colour. Taste of the solution slightly acid and bitter. Not precipitated by carbonate of soda, ammonia, nitrate of silver, nor acetate of lead. The orange substance has a bitter taste. When heated, readily swells and blackens, but does not flame. Burns without leaving any residuum. Lighter than water. When agitated in water, tinges it yellow, but does not all dissolve. The specific gravity of ammoniac is 1.207. Mr Hatchett found it soluble in alkalies. Neither alcohol nor water, when distilled off it, bring over any thing.

According to the analysis of Braconnot ammoniac is composed of the following ingredients :

70.0	resin
18.4	gum
4.4	glutinous matter
6.0	water
1.2	loss

---

100.0

The resin he found brittle and yellow. In these respects

it differs from the resin which I extracted from ammoniac, which was soft, and continued so after being exposed to the air for two months. This difference is probably owing to the state of the ammoniac, sometimes it is brittle and yellow, at other times soft and white. It was in this last state that I examined it. Braconnot found the yellow matter into which this resin is converted by nitric acid soluble in hot alcohol and water. It had the property of dyeing silk a fine yellow colour, not altered by oxymuriatic acid. The gum which he extracted from ammoniac possessed the properties of common gum as far as he examined them. It is transparent, yellowish, brittle, soluble in water, and precipitated by acetate of lead, but not by the superacetate nor the nitrate of lead. The mercurial salts render the solution milky. By nitric acid it is converted into saccharic and oxalic acids, and furnishes also a little lactic acid. The glutinous matter was insoluble in water and alcohol; it became black when dried, and yielded a yellow matter and some oxalic acid when treated with nitric acid\*.

•Libanum.

3. *Olibanum*.—This substance is obtained from *juniperus lycia*, and is chiefly collected in Arabia; it is the frankincense of the ancients. It is in the form of brittle masses about the size of a chestnut. The colour is yellow. It has a bitterish nauseous taste, when burnt diffuses an agreeable odour. Alcohol dissolves  $\frac{1}{4}$ ths of it; and water about  $\frac{1}{4}$ ths. When distilled it yields a little volatile oil; but gives no

\* *Ann. de Chim.* lxxviii. 69.

either with water or alcohol \*. Its specific gravity is  $\frac{1}{2}$  1.73 †. Chap. I.

4. *Sagapenum*.—The plant which yields this gum Sagapenum.  
resin is not well known; but it is suspected to be the  
*ferula persica*. The substance itself is brought to Eu-  
rope from Alexandria. It is commonly in tears agglu-  
tinated together. Colour yellow. Taste hot and bit-  
ter. Smell alliaceous. Softens between the fingers,  
but does not melt when heated. Sparingly soluble in  
water, but almost completely soluble in alcohol. When  
distilled with water it yields a little volatile oil. The  
water is strongly impregnated with the flavour of the  
*sagapenum* †.

5. *Asafetida*.—This substance is obtained from the Asafetida.  
*ferula asafetida*, a perennial plant which is a native of  
Persia. When the plant is about four years old, its  
roots are dug up and cleaned. Their extremity being  
then cut off, a milky juice exudes, which is collected.  
Then another portion is cut off, and more juice exudes.  
This is continued till the roots are exhausted. The  
juice thus collected soon hardens and constitutes *asafa-*  
*tida*. It comes to Europe in small grains of different  
colours, whitish, reddish, violet, brown. Pretty hard,  
but brittle. Its taste is acrid and bitter; its smell  
strongly alliaceous and fetid. Alcohol, according to  
Neumann, dissolves about  $\frac{1}{3}$  ths of this substance; and  
water takes up nearly  $\frac{1}{4}$  th if applied before the spirit.  
A considerable portion of earthy matter remains undis-  
solved. It yields a volatile oil, both when distilled

\* Neumann's *Chem.* p. 315.

† Brisson.

† Neumann's *Chem.* p. 316.

Vol. V.

K



Book IV.

with water and alcohol. This oil possesses the acrid properties of the *asafœtida* itself \*. The specific gravity of the gum resin is 1.327.

Scammony.

6. *Scammony*.—This substance is obtained from *convolvulus scammonia*, a climbing plant which grows in Syria, and was first correctly described by Dr Lavesol †. The roots when cut yield a milky juice. When collected and allowed to harden constitutes scammony. Colour dark grey or black. Smell, peculiar and nauseous: taste bitter and acrid. With water forms a greenish-coloured opaque liquid. Alcohol dissolves the greatest part of it. It is usually mixed with the expressed juice of the root, and frequently also with other impurities, which alter its appearance. In medicine it operates as a strong cathartic. Its specific gravity is 1.235 ‡.

Opoponax.

7. *Opoponax*.—This substance is obtained from *pastinaca opoponax*, a plant which is a native of the countries round the Levant. The gum resin, like other resins, is obtained by wounding the roots of the plant. The milky juice, when dried in the sun, constitutes opoponax. It is in lumps of a reddish yellow colour and white within. Smell peculiar. Taste bitter and acrid. With water it forms a milky solution, about one-half of it dissolves. Alcohol acts but feebly. When distilled with water or alcohol, these liquids acquire the flavour of opoponax, but no oil separates. Its specific gravity is 1.622 §.

---

\* Neumann's *Chemistry*, p. 312.

† See an abridgment of his account by Dr Lewis, Neumann's *p.* 303.  
‡ Brisson.  
§ Neumann's *Chem.* p. 316.

8. *Gamboge* or *Gumgutt*.—This substance is obtained from the *stalagmitis gambogioides*, a tree which grows wild in the East Indies. In Siam it is obtained in drops by wounding the shoots; in Ceylon it exudes from wounds in the bark. It is brought to Europe in large cakes. Its colour is yellow; it is opaque, brittle, and breaks vitreous. It has no smell, and very little taste. With water it forms a yellow turbid liquid. Alcohol dissolves it almost completely; and when mixed with water becomes turbid, unless the solution contain ammonia. In that case acids throw down an insoluble yellow precipitate. It operates, when taken internally, as a most violent cathartic. Its specific gravity is 1.221\*. It appears that it was brought to Europe by the Dutch about the middle of the 17th century†. It forms a fine yellow paint, and stains hot marble of a fine lemon yellow‡.

Chap. I.  
Gamboge.

Braconnet analysed, it and found it composed of one part of a gum which possessed the properties of cherry tree gum, and four parts of a reddish brittle resin which possessed the characteristic properties of the resins. It dissolved in alcohol and alkalies, and by nitric acid was converted into a yellowish bitter matter. Oxymuriatic acid deprived it of its dark colour, and a combination took place between it and muriatic acid, in which it neutralized that acid§.

9. *Myrrb*.—The plant from which this substance is obtained is unknown. If we believe Bruce it belongs

Myrrb.

\* Braconet.

† See the *Anatomia Essentiarum Vegetabilium* of Angelus Sala, p. 31.

‡ Lewis, Neumann's *Chem.* p. 300.

§ *Ann. de Chim.* lxxviii. 23.

Book IV.

to the genus of *mimosa*. It grows in Abyssinia and Arabia. It is in the form of tears. Colour reddish yellow; when pure somewhat transparent, but it is often opaque. Odour peculiar. Taste bitter and aromatic. Does not melt when heated, and burns with difficulty. With water it forms a yellow opaque solution. The solution in alcohol becomes opaque when mixed with water, but no precipitate appears. By distillation with water it yields an oil heavier than water; but nothing comes over with alcohol\*. Its specific gravity is 1.360 †. It is employed in medicine. Mr Hatchett found it soluble in alkalis.

From the analysis of Braconnot it appears that myrrh is composed of about

23 resin
77 gum
<hr/>
100

The resin is reddish, has a bitter taste and the peculiar odour of myrrh. The gum differs in its properties from every other gummy substance hitherto examined. It has a dark brown colour; is at first soluble in water, but by boiling the liquid, or by exposing the gum to heat, it acquires cohesive properties, and becomes insoluble in water. When distilled it yields ammonia, and when dissolved in nitric acid azotic gas is disengaged. These properties show an analogy between it and animal substances. It is precipitated by the salts of lead, mercury, and tin, and it falls in combination with the oxides of these metals †.

---

\* Lewis, Neumann's *Chem.* p. 317.

† Brisson.

† *Ann. de Chim.* lxxiii. 52.

10. *Euphorbium*.—This substance is obtained from the *euphorbia officinalis*. The milky juice which exudes from that plant, when dried in the sun, constitutes euphorbium. It is brought from Africa in small yellow tears. It has no smell, and is mostly soluble in alcohol. Its specific gravity is 1.124 †. It is considered as poisonous.

Chap. I.  
Euphor-  
bium.

According to the analysis of Braconnot it is composed of

37.0	resin
19.0	wax
20.5	malate of lime
2.0	Malate of potash
5.0	Water
13.5	Woody matter
3.0	Loss

---

100.0

The resin has peculiar properties. It is reddish and transparent, excessively acrid, and possesses poisonous properties. It is insoluble in alkalies, but soluble in sulphuric and nitric acids. These properties show it to be a peculiar vegetable principle. The wax possesses the properties of bees wax. The malate of lime had been mistaken for gum †.

11. Little is known concerning the substances called *bdeesium* and *caranna*, reckoned among the gum resins. The specific gravity of the first is 1.371, of the second 1.124 ‡. Bdeesium was celebrated by the ancient physicians. It comes from Arabia. The substance ex-

---

† Brisson.

‡ *Ann. de Chim.* lxxviii. 44.

§ Brisson.



Book IV. *tracted from ivy, and known by the name of gumme-dera, is considered at present as a gum resin; but I do not know that it has been chemically examined. Its specific gravity is 1.294.*

12. From the experiments made upon ipecacuan, the root of the *cephelis ipecacuanha*, especially by Dr Irvine, we learn that it also contains a gum resin. The same remark applies to several other vegetable substances employed in medicine.

It deserves attention, that the gum resins, when subjected to destructive distillation, yield all of them a portion of ammonia; a proof that they all contain azote. In this respect they agree with gum and extractive.

---

## SECT. XXVIII.

### OF COTTON.

**COTTON** is a soft down which envelopes the seeds of various plants, especially the different species of *gossypium*, from which the cotton of commerce is procured. *Origin.* These plants are natives of warm climates; grow wild in Asia, Africa, and America, within the tropics; and are cultivated in the East and West Indies. The finest cotton, according to Mr Edwards, is distinguished by the name of *green seed cotton*, from the colour of its seeds\*, and is perhaps the produce of the *gossy-*

---

\* *History of the West Indies*, ii. 264.

*gossypium hirsutum*. There are two species of it; in one of which the cotton does not easily part from the seeds. But the cotton plant commonly cultivated is a shrub, of which Mr Edwards enumerates five kinds; namely, the common Jamaica, the brown bearded, the nankeen, the French (*gossypium arboreum*), and the kidney cotton\*. When the seeds are ripe, the pods open, and display the cotton, which is collected and separated from the seeds by means of rollers.

Cotton, when spun and woven into cloth, furnishes garments to a very considerable portion of the civilized world. The quantity annually brought into this country, and spun by machinery, is not less than 20 millions of pounds; and the number of individuals employed in manufacturing it cannot be less than 700,000. It constitutes therefore one of the most important of our manufactures.

Though no correct chemical investigation of the properties of cotton has hitherto been made, yet as its obvious qualities distinguish it sufficiently from every other vegetable substance, we must consider it as a peculiar vegetable principle; and I have introduced it here, in hopes that some person or other will be induced to examine its nature in detail. The following are the particulars at present known.

This substance is in threads differing in length and in fineness. No asperities can be discovered on the surface of these threads; but if Lewenhoeck's microscopical observations are to be trusted, they are all tri-

\* Properties.

\* Perhaps the first species are only varieties of the *gossypium hirsutum*.

**Book IV.**

angular, and have three sharp edges. Cotton discolours considerably in colour; but when *bleached* it becomes of a fine white.

Cotton is tasteless and destitute of smell. It is completely insoluble in water, alcohol, ether, and oils, in all the vegetable acids.

The diluted alkaline leys have no perceptible action on cotton; but when very strong they dissolve it assisted by a sufficient degree of heat. The new ducts obtained by this solution have not been examined.

Cotton has a strong affinity for some of the earths, especially for alumina. Hence this substance is used to fix colours on cotton. The cloth is steeped in a solution of alum or acetate of alumina, and afterwards dyed.

Several of the metallic oxides also combine with cotton readily, and remain united with much obstinacy. The oxide of iron is one of the most remarkable. When cotton is dipped into a solution of iron in an acid, it comes out yellow, and the iron is neither separated by alkalis nor soap, nor even by acids, unless when the combination is quite recent. The colour gradually fades by exposure to the air, owing no doubt to the oxidization of the iron, unless the cloth be steeped in an aluminous solution, which prevents the colour from becoming disagreeable, probably by diluting it\*. Oxide of tin also combines with cotton, and is frequently used as a mordant.

Cotton combines readily with tannin, and forms

---

\* See Chaptal, *Ann. de Chim.* xxvi. 266.

yellow or brown compound. Hence the infusion of galls, and of other astringent substances, is often used as a mordant for cotton.

Nitric acid decomposes cotton when assisted with heat, and oxalic acid is formed; the other products have not been examined. Sulphuric acid likewise chars it. Oxymuriatic acid gas bleaches it, and probably alters and dissolves it when applied in a concentrated state.

Cotton is extremely combustible, and burns with a clear lively flame. The ashes left behind, according to Neumann, contain some potash. When distilled it yields a great portion of acidulous water, and a small quantity of oil, but no ammonia\*.

---

## SECT. XXIX.

### OF SUBER.

THIS name has been introduced into chemistry by Fourcroy, to denote the outer bark of the *quercus suber*, or the common cork; a substance which possesses properties different from all other vegetable bodies.

It is exceedingly light, soft, and elastic; very combustible, burning with a bright white flame, and leaving a light black bulky charcoal; and when distilled yields a little ammonia.

---

\* Neumann's *Chem.* p. 430.



Book IV.  
Properties.

When digested in water, a yellowish-coloured solution is obtained, seemingly containing extractive, nearly the same proportion is taken up by alcohol. Sulphuric acid readily chars it. Nitric acid gives it yellow colour, corrodes, dissolves, and decomposes it converting it partly into suberic acid, partly into a substance resembling wax, partly into artificial tannin, and partly into a kind of starchy matter †.

Fourcroy supposes, from some experiments which I does not relate, that the epidermis of all trees is a substance possessed of the same properties with cork; and perhaps we may conclude from the experiments of Linn that all vegetable membrane possesses nearly the same chemical characters. At least it agrees with cork in furnishing suberic acid when treated with nitric acid ‡.

---

## SECT. XXX.

### OF WOOD.

**A**LL trees, and most other plants, contain a particular substance, well known by the name of *wood*. If a piece

---

\* Neumann's *Chemistry*, p. 428.

† Bouillon La Grange, *Ann. de Chim.* xliii. 50.

‡ Nicholson's *Jour.* xliii. 155.

of wood be well dried, and digested, first in a sufficient quantity of water and then of alcohol, to extract from it all the substances soluble in these liquids, there remains only behind the *woody fibre*.

This substance, which constitutes the basis of wood, is composed of longitudinal fibres, easily subdivided into a number of smaller fibres. It is somewhat transparent; is perfectly tasteless; has no smell; and is not altered by exposure to the atmosphere.

It is insoluble in water and in alcohol. The fixed alkalies, when assisted by heat, give it a deep brown colour, render it soft, and decompose it. A weak alkaline solution dissolve it without alteration; and it may be thrown down again by means of an acid. By this property we are enabled to separate wood from most of the other vegetable principles, as few of them are soluble in weak alkaline leys.

Properties

When heated, it blackens without melting or frothing up, and exhales a disagreeable acrid fume, and leaves a charcoal which retains exactly the form of the original mass. When distilled in a retort, it yields an acid liquor of a peculiar taste and smell, distinguished by the name of *pyrolignous*, and formerly considered as a distinct acid; but Fourcroy and Vauquelin have lately ascertained that it is merely the acetic acid combined with an empyreumatic oil\*.

Action of heat,

---

\* Mollat is said to have succeeded in France in making acetic acid from wood as pure as radical vinegar. It answers very well for aromatic vinegar, but possesses a little acrimony, which makes it less fit for the table. See Nicholson's *Jour.* xxiv. 70.

Book IV.  
Of nitric  
acid.

By nitric acid Fourcroy converted the residuum of quinquina, which does not seem to differ from the woody fibre, into oxalic acid; at the same time there was a little citric acid formed, and a very small quantity of malic and acetic acids. Some azotic gas also was disengaged.

By this process he obtained from 100 parts of woody fibre

56·250 oxalic acid  
3·905 citric acid  
0·388 malic acid  
0·486 acetic acid  
0·867 azotic gas  
8·330 carbonate of lime

---

70·226

32·031 residuum

---

102·257

There was likewise a quantity of carbonic acid gas disengaged, the weight of which was unknown. This increase of weight in the product was evidently owing to the oxygen derived from the nitric acid\*.

When this residuum was distilled in a retort, 104 parts yielded the following products :

---

\* *Ann. de Chim.* viii. 153.

20 of a yellow liquid, containing alcohol, and an acid which had the smell of pyromucous.

77 of concrete oil, mostly soluble in alcohol

95 charcoal }  
67 carbonate of lime } in the retort

59

41 gas, half carbonic acid, half carbureted hydrogen

90 \*

When wood is burnt with a smothered flame, it leaves well known, a quantity of charcoal behind it, exhibits the exact form, and even the different of the original wood. As it is the *wood* alone undergoes this change, while the other components of the plant are dissipated, we may form notion of the relative proportion of wood which different plants contain, by the proportion of charcoal they yield. Now, the quantity of charcoal yielded by 100 of different trees is, according to the experiments of Proust, as follows :

Black ash.....	0.25
Guaiacum.....	0.24
Pine.....	0.20
Green oak.....	0.20
Heart of oak.....	0.19
Wild ash.....	0.17
White ash.....	0.17

From the facts above related, it appears that the composition of plants is composed of oxygen, carbon, hydro-

\* *Ann. de Chim.* viii. 251.



**Book IV.** gen, azote, and lime. Mr Chaptal supposes that mucilage differs from woody fibre merely in containing less oxygen. We are certain at least that mucilage or gum is composed of the same ingredients; and Mr Chaptal has shown, that the juices of plants are partly converted into a substance similar to woody fibre by oxymuriatic acid, which imparts to them oxygen\*. These juices contain both gum and resin: after the formation of the woody fibre the resin is still unaltered. This gives some probability to his opinion, provided it can be proved that extractive, by combining with oxygen, assumes the properties of wood; for the precipitate observed by Chaptal was undoubtedly extractive.

---

## SECT. XXXI.

### OF ALKALIES.

**T**HE only alkalies found in plants are potash and soda. Ammonia may indeed be obtained by distilling many vegetable substances, but it is produced during the operation. One or other of these alkalies is found in every plant which has hitherto been examined. The quantity indeed is usually very small. From the experiments of Vauquelin, it is probable that the alkalies are combined in plants with acetic and carbonic acids.

---

\* *Ann. de Chim.* xxi. 285.

Potash is found in almost all plants which grow at a distance from the sea. It may be extracted by burning the vegetable, washing the ashes in water, filtering the water, and evaporating it to dryness. It is in this manner that all the potash of commerce is procured. The following Table exhibits the quantity of ashes of potash which may be extracted from 100 parts of various plants :

Flow.....	2.8	0.285 *
Lin.....	2.36727	0.39 †
Lin.....	1.35185	0.15349
Lin.....	1.23476	0.07481
Lin.....	1.1283	0.1254
Lin.....	0.58432	0.14572
Lin.....	0.34133	
Lin branches.....	3.379	0.55 †
Common nettle.....	10.67186	2.5033

Those marked † are from Kirwan, *Trans. v. 164*. The rest from Berthollet, *Ann. de Chim.* xix. 178. The following Table, by Redi, of acids and salts yielded by different plants, is worth inserting. It is given in the *Phil. Trans.* for 1698 (vol. xx. p. 281.)

Vegetables.	Ashes. lbs. oz. dr.	Salts. oz. dr.
Of dried flowers of oranges	4 6 0	0 5
Of gourds new gathered, which dried in the oven were 36 lbs	4 0 0	10 0
Red onions (being 720) roasted, the coals turned to 16 lbs to the coals new added 4 oz. of sulphur	1 6 0	3 2
Eyebright fresh, and afterwards stilled and burnt	5 0 0	4 0
Distilled roses	4 0 1	0 0
Of maidenhair	9 0 0	0 4
Roots of black hellebore, which dried came to 50 lbs.	6 0 0	1 0
Roots of white hellebore, fresh, which dried came to 50 lbs.	2 0 0	4 0

## Book IV.

Common thistle .....	4.04265	0.53734
Fern .....	5.00781	0.6259
Cow thistle .....	10.5	1.96693
Great river rush .....	3.85395	0.72234
Feathered rush .....	4.33593	0.50811
Stalks of turkey wheat. 8.86		1.75 †
Wormwood.....	0.744	7.8
Fumitory.....	21.9	7.9 †
Trifolium pratense.....		0.078 †
Vetches.....		2.75 †
Beans with their stalks.....		2.0 †

Pounds.	Vegetables.	Ashes. lbs. oz. dr.	Salts. oz. dr.
96	Roots dried and burnt of fresh esula	3 0 0	0
30	Roots of liquorice - -	1 9 0	1 4
20	Pellitory - -	1 0	0 6
100	Green endive - -	2 0 0	2 0
90	Green bindweed - -	1 0 0	2
2000	Leaves of laurel - -	33 0 4	0 0
500	Leaves of laurel - -	6 0 0	10
1000	Water melons well ripe, the seeds bo- ing taken - -	25 0 1	9
2400	Cucumbers - -	18 0 0	0
300	Wood of ivy - -	9 0 0	0
50	Scorzonera dried - -	8 0 0	0
300	Pine apples, the nuts taken out - -	3 0 0	0
150	Mugwort dried - -	8 0 0	0
130	Leaves of cyprus - -	6 0 0	0
10	Peel of pomegranates dried - -	0 8 0	0
2	Sassafras - -	0 0 0	0
12	Lignum sanctum - -	2 6 0	0
4	Yellow sanders - -	0 1 4	0
4	Black pepper - -	0 2 4	0
30	Ginger - -	1 7 0	0
12	Turbith - -	1 0 0	0
	Wood of fir - -	3 0 0	0
	Scopæ - -	16 1 1	
	Scopæ - -	16	

In general, three times as much ashes are obtained from shrubs, and five times as much from herbs, as from trees. Equal weights of the branches of trees produce more ashes than the trunk, and the leaves more than the branches. Herbs arrived at maturity produce more ashes than at any other time. Green vegetables produce more ashes than dry \*.

The salt which is obtained from plants does not consist wholly of potash, there are other salts mixed with it; these usually are sulphate of potash, muriate of potash, sulphate of lime, phosphate of lime, &c.; but these bear, in general, but a small proportion to the potash. The ashes consist of potash mixed with earths.

Some judgment may be formed of the quantity of potash which a plant contains, from the quantity of ashes which it yields: but the above Table is sufficient to show us, that were we to trust to that we would often be misled.

2. Soda is found in almost all the plants which grow in the sea, and in many of those which grow on the shore. In general, the quantity of soda which plants contain bears a much greater proportion to their weight than the potash does which is found in inland vegetables. 100 parts of the *salsola soda*, for instance, yield 19.921 of ashes; and these contain 1.992 parts of soda; some of which, however, is combined with muriatic acid †. The plants from which the greater part of the soda, or *barilba* as it is called, which is imported from Spain, is extracted, are the *salsola sativa* and *verniculata*.

\* *Ann. de Chim.*  
Vol. I.

† Vauquelin, *Ibid.* xviii. 77.



## SECT. XXXII.

## OF EARTHS.

THE only earths hitherto found in plants are the four following ; *lime, silica, magnesia, alumina.*

Lime.

1. Lime is usually the most abundant of the earth of plants, and the most generally diffused over the vegetable kingdom. Indeed it is a very uncommon thing to find a plant entirely destitute of lime : *salsola soda* almost the only one in which we know for certain that this earth does not exist \*.

Silica.

2. Silica exists also in many plants, particularly in grasses and equisetums. Mr Davy has ascertained that it forms a part of the epidermis, or outermost bark of these plants ; and that in some of them almost the whole epidermis is silica.

Parts Silica.

100 parts of the epid. of bonnet cane yielded	90
bamboo.....	71·4
(arundo phragm,) common reed ....	48·1
stalks of corn.....	6·5

The concretions which are sometimes found in the

---

\* Vauquelin, *Ann. de Chim.* xviii. 76.

ycane called tabasheer, have been ascertained  
Macie to be composed of pure silica †.

Chap. I.

Magnesia does not exist so generally in the vege-  
ingdom as the two preceding earths. It has been  
however, in considerable quantities in several  
sts, especially fuci \*\*; but the salsola soda con-  
greater proportion of magnesia than any plant  
examined. Mr Vauquelin found that 100  
f it contained 17.929 of that earth ¶.

Magnesia.

Alumina has only been found in very small quan-  
plants.

Alumina.

Following Table will show the quantity of these  
rths which exist in several vegetables.

10 parts of oak contains of earths.....	1.03
Beech.....	0.459 †
Fir.....	0.003 †
Turkey wheat.....	7.11 †
Sunflower.....	3.72 †
Vine branches.....	2.85 †
Box.....	2.674 †
Willow.....	2.515 †
Elm.....	1.96 †
Aspin.....	1.146 †
Fern.....	3.221 *
Wormwood.....	2.444 §
Fumitory.....	14.000 §

artroy and Vauquelin lately examined a tabasheer from the Andes.  
d it composed of 70 silica and 30 potash. Gehlen's Jour. Second  
ii. 112.

Vauquelin, *Ann. de Chim.* xviii. 86. and ix. 94. ¶ Ibid. p. 78.

† Kirwan, *Irish Trans.* iii. 35.

§ Wiegleb.

Book IV.

This Table shows us that the quantity of earth is greater in herbs than in trees.

Bergman found all the four earths in every kind of grain which he analysed \*.

Vauquelin found that 100 parts of oat grain leave 3.1591 of residuum. This residuum is composed of

60.7 silica

39.3 phosphate of lime

---

100.0 †

When the whole of the *avena sativa*, however, stalk and seed together, is burnt, it leaves a residuum composed of.....55 silica

15 phosphate of lime

20 potash

5 carbonate of lime

---

95 and a little oxide of iron ‡

This shows us that the stalk contains several substances not to be found in the grain.

The following Table exhibits the quantity of earth and metallic oxides in grains, obtained by Schreber from 32 ounces of the seeds of the following kinds: corn; wheat (*tritium hybernium*), rye (*secale cereale*), barley (*hordeum vulgare*), oats (*avena sativa*), and likewise from the same quantity of rye straw §.

---

\* Opusc. v. 94.

† Ibid. 19.

‡ Ann. de Chim. xxix. 17.

§ Gehlen's Jour. III. 515.

	Wheat.	Rye.	Barley.	Oats.	Rye Straw.
...	13.2	15.6	66.7	144.2	152
Carbonate of lime	12.0	13.4	24.8	33.75	46.2
Carbonate of magnesia	13.4	14.2	25.3	33.9	28.2
...mina	0.6	1.4	4.2	4.5	3.2
...de of manganese	5.0	3.2	6.7	6.95	6.8
...de of iron	2.5	0.9	3.8	4.5	2.4
	47.3	48.7	131.5	227.8	234.8

Earths in  
corn.

Saussure junior, in his *Chemical Researches on Vegetation*, a work published in 1804, has given us the most valuable table of the earthy and saline constituents of vegetables which has yet appeared. This table is the more valuable, as it was constructed entirely from his experiments. For that reason I shall insert it in place:

TABLE OF INCINERATIONS.

Constituents of 100 parts of the Ashes.

Saussure's  
table.

Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Lime.
Leaves of oak ( <i>Quercus robur</i> ), May 10.	13	53	745	47	34	0.12	3	0.64	15.24
Ditto, Sept. 27.	24	55	542	17	18.25	23	4.5	1.75	25.5
Wood of a young oak, May 10.		4		26	28.5	12.25	0.12	1	12.55
Stalk of ditto.		60		7	4.5	63.25	0.25	1.75	12.75



TABLE OF INCINERATIONS.					Constit. of 100 parts of the ashes.					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
5	Perfect wood of oak.		2		38.6	4.5	32	2	2.25	101
6	Albumen of do.				32	24	11	7.5	2	113
7	Bark of ditto.		60		7	3	66	1.5	2	121
8	Corrical layers of ditto.		73		7	3.75	65	0.5	1	121
9	Extract of wood of ditto.		61		11					
10	Soil from wood of ditto.		41		24	10.5	10	32	14	81
11	Extract from do.		111		66					
12	Leaves of poplar ( <i>populus nigra</i> ), May 16.	23	66	652	36	13	29	5	1.25	151
13	Ditto Sept. 12.	41	93	565	26	7	36	11.5	1.5	161
14	Wood of ditto, Sept. 12.		8	26		16.75	27	3.3	1.5	143
15	Bark of ditto.		72		6	5.3	60	4	1.5	123
16	Leaves of hazel ( <i>corylus avellana</i> ), May 1.		61		26	23.3	22	2.5	1.5	147
17	Ditto washed in cold water.		57		8.2	19.5	44.1	4	2	122
18	Leaves of ditto, June 21.	28	62	655	22.7	14	29	12.3	1.5	153

TABLE continued.

Chap. I.

OF INCINERATIONS.			Constic. of 100 parts of the ashes.						
	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
pt. 20.	31	70	557	11	12	36	22	2	17
of ditto.		5		24.5	35	8	0.55	0.12	12.2
ditto.		62		12.5	5.5	54	0.25	1.75	26
wood of T. (see p. 10), N. 10.		7		21	22.5	56	0.12	0.25	10.38
n of ditto.		13		26	17.25	24	2	0.25	11.5
ditto.		89		7	8.5	15	15.25	1.12	13.13
layers of		82		10	16.5	48	0.12	1	24.38
wood of am (see p. 10), N. 10.	4	6	346	22	23	26	0.12	2.25	16.63
n of do.	4	7	390	18	36	15	11	1	19
ditto.	88	134	346	4.5	4.5	59	1.5	0.12	30.38
of horse T. (see p. 10), May 10.		35		9.5					
of ditto.	16	72	782	50					
ly 23	29	64	652	24					
pt. 27.	31	86	616	13.5					

TABLE OF INCINERATIONS.					Constit. of 100 parts of the ashes.					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
33	Flowers of ditto, May 10.	9	1	873	30					
34	Fruit of ditto, October 5.	12	14	647	81	12	0	0.5	0.25	5.25
35	Plants of pease ( <i>pisum sativum</i> ), in flower.		95		49.3	17.25	6	2.3	1	28.65
36	Ditto ripe,		81		34.25	12	14	11	2.5	17.25
37	Plants of vetch ( <i>vicia faba</i> ), before flowering, May 23.	16	150	895	15.5	14.5	3.5	1.5	0.5	14.50
38	Ditto in flower, June 23.	20	122	876	51.5	13.5	4.12	1.5	0.5	14.38
39	Ditto ripe, July 23.		66		0	17.75	4	1.75	0.5	16
40	Ditto, seeds separated.		115		42	5.75	36	1.75	1	12.9
41	Seeds of ditto.		33		69.28	27.92	0	0	0.5	23
42	Ditto in flower, raised in distilled water.		39		60.1	30	0	0	0.5	9.4
43	<i>Salvado vulgaris</i> , before flowering, May 1		92		67.5	10.75	1.5	1.5	0.75	11.1
44	Ditto just in flower, July 15.		57		59	59	1.5	1.5	0.75	11.1

TABLE continued.

Chap. I.

ANALYSIS OF INCINERATIONS.				Const. of 100 parts of the ashes.					
Names of plants.	Ashes from 100 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
no seeds ripe, Sept 20.		50		48	11	17.25	3.5	1.5	18.75
seeds of ruminant (Sesuvium), a month before flowering, June 23.		147		63	6.7	11.56	1.5	0.12	16.67
no in flower, July 23.	13	137	877	61	6	12.5	1.5	0.12	18.78
no bearing ripe, Sept 20.	23	93	753	51.5	22.5	4	3.75	0.5	17.75
heat (triticum) in flower.				43.25	12.75	0.25	12	0.5	12.25
no seeds ripe.				11	15	0.25	5.4	1	18.75
no a month before flowering		79		60	11.5	0.25	12.5	0.25	15.5
no in flower, June 14.	16	54	699	41	10.75	0.25	26	0.5	21.5
no seeds ripe.		33		10	11.75	0.25	5.1	0.75	23
row of wheat.		43		22.5	6.2	1	6.5	1	7.8
seeds of ditto.		13		47.16	44.5	0	0.5	0.25	7.6
ditto.		52		4.16	46.5	0	0.5	0.25	8.6
seeds of maize (Zea mays), a month before flowering, June 23.		122			7.25	0.25	7.5	0.25	17.25



TABLE OF INCINERATIONS.				Constit. of 100 parts of the Ashes					
	Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallie oxides.
58	Ditto in flower, July 23.	81			69	6	0.25	7.5	0.25 17
59	Ditto seeds ripe	46							
60	Stalks of ditto.	84			72.45	5	1	18	0.5 31
61	Spikes of ditto.	16							
62	Seeds of ditto.	10			62	36	0	1	0.12 01
63	Chaff of barley ( <i>bardeum vulgare</i> ).	42			20	7.75	12.5	57	0.5 21
64	Seeds of ditto.	18			29	32.5	0	35.5	0.25 21
65	Ditto.				22	22	0	22	0.32 291
66	Oars.	31			1	24	0	60	0.25 147
67	Leaves of <i>rhododendron ferrugineum</i> , raised on Jura, a limestone hill, June 20.	30			23	14	43.25	0.75	3.25 156
68	Ditto raised on Breven, a granite hill, June 27.	45			21.2	16.75	16.75	2	5.75 31.5
69	Branches of ditto, June 20.	8			22.5	10	39	0.5	5.4 22.4
70	Spikes of ditto, June 27.	8			14	11.5	29	1	11 24.5

TABLE continued.

Chap. J.

TABLE OF INCINERATIONS.				Constit. of 100 parts of the ashes.					
Names of plants.	Ashes from 1000 parts of the plant green.	Ditto dry.	Water from 1000 parts of the plant green.	Soluble salts.	Earthy phosphates.	Earthy carbonates.	Silica.	Metallic oxides.	Loss.
As of fir ( <i>pinus sylvestris</i> ) raised on Jura, No 20.	29			16	12.25	43.5	2.5	1.6	24.13
As raised on Jura, June 20.	29			15	12	29	19	5.5	19.5
As of pine, No 20.	15			15					
Berry ( <i>vacca myrtillus</i> ) raised on Jura, No 29.	26			17	18	42	0.5	3.12	19.38
As raised on Jura, Aug. 20.	22			14	22	22	5	9.5	17.5
As from <i>rhododendron ferrugineum</i> of No 68 and 69.	65			0.5	6	29	28	18	15.5
As from soil (lito).	140			53	17.25	21.5	3.25	3	1.88
As of <i>rhododendron ferrugineum</i> raised on a porous earth No 68 and 69.	620								
As from the red sand.	142			24	13	17	14	10	1.88

---

 SECT. XXXIII.

## OF METALS.

SEVERAL metallic substances have also been found in the ashes of vegetables, but their quantity is exceedingly small; so small, indeed, that without very delicate experiments their presence cannot even be detected.

The metals hitherto discovered are iron, which is far the most common, manganese, and, if we believe some chemists, gold.

1. Iron has been found in many plants; the ashes of *salsola* contain a considerable quantity of it. From experiments of Mr Grimshaw, it appears that six ounces of cotton cloth, unbleached, contain about four grains of iron, and six ounces of linen in the same state about three grains; but it is likely, as Mr Grimshaw observes, that part of this iron is communicated to the cloth by the weaver's dressing. When it gets acid, and is allowed to remain in iron pans, it must take up a considerable quantity of the metal\*.

2. Scheele first detected manganese in vegetable ashes. Proust found it in the ashes of the pine, *calendula*, green oak, and fig-tree†.

---

 \* *Phil. Mag.* xvi. 33.
† *Opusc.* i. 106.
‡ *Phil. Mag.* v.

3. With respect to the minute portion of gold extracted from the ashes of plants by Kunkel, Sage, &c. it is probable that it proceeded rather from the lead which they employed in their processes than from the ashes.

---

#### SECT. XXXIV.

##### OF VEGETABLE PRINCIPLES IN GENERAL.

In the preceding Sections a pretty full account has been given of the different vegetable principles hitherto examined by chemists. They amount to no fewer than 33 genera. But the three last of these, namely, the alkalies, earths, and metals, occur usually in such small proportions, that they are scarcely entitled to the name of vegetable principles. Besides, it is highly probable that they are taken up ready formed, and deposited without alteration in the vegetables which contain them; whereas the other 30 genera consist of substances which owe their formation to the processes of vegetation. It is of them, of course, that vegetables are formed; they are the substances which come into view when vegetables are analysed. It is necessary therefore to be well acquainted with their essential characters, that we may know the marks by which they are to be recognised. These unfortunately are sometimes ambi-



## Book IV.

## Table of essential characters.

gnous; so that a good deal of skill and experience ~~are~~ necessary before we can distinguish them readily. Some of them indeed are so imperfectly known, that we ~~are~~ in possession of no good characteristic marks. The following Table contains a general view of the most striking properties of the different genera.

1. *Sugar*.—Crystallizes. Soluble in water and alcohol. Taste sweet. Soluble in nitric acid, and yields oxalic acid.

2. *Sarcocoll*.—Does not crystallize. Soluble in water and alcohol. Taste bitter sweet. Soluble in nitric acid, and yields oxalic acid.

3. *Asparagin*.—Crystallizes. Taste cooling and nauseous. Soluble in hot water. Insoluble in alcohol. Soluble in nitric acid, and converted into bitter principle or artificial tannin.

4. *Gum*.—Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Precipitated by silicated potash. Soluble in nitric acid, and forms saccharic and oxalic acids.

5. *Mucus*. Does not crystallize. Taste insipid. Soluble in water, and forms mucilage. Insoluble in alcohol. Not precipitated by silicated potash. Precipitated by alcohol from water in a fibrous form without rendering the liquid opaque.

6. *Ulm*.—Does not crystallize. Taste insipid. Soluble in water, and does not form mucilage. Precipitated by nitric and oxymuriatic acids in the state of resin. Insoluble in alcohol.

7. *Inulin*.—A white powder. Insoluble in cold water. Soluble in boiling water; but precipitates unaltered after the solution cools. Insoluble in alcohol. Soluble in nitric acid, and yields oxalic acid.

8. *Starch*.—A white powder. Taste insipid. Insoluble in cold water. Soluble in hot solution; opaque and glutinous. Precipitated by infusion of nutgalls; precipitate redissolved by a heat of  $120^{\circ}$ . Insoluble in alcohol. Soluble in dilute nitric acid, and precipitated by alcohol. Yields with nitric acid oxalic acid, and a waxy matter.

9. *Indigo*.—A blue powder. Taste insipid. Insoluble in water, alcohol, ether. Soluble in sulphuric acid. Soluble in nitric acid, and converted into bitter principle and artificial tannin. Volatilized by heat in a purple smoke.

10. *Gluten*.—Forms a ductile elastic mass with water. Partially soluble in water; precipitated by infusion of nutgalls and oxymuriatic acid. Soluble in acetic acid and muriatic acid. Insoluble in alcohol. By fermentation becomes viscid and adhesive, and then assumes the properties of cheese. Soluble in nitric acid, and yields oxalic acid.

11. *Albumen*.—Soluble in cold water. Coagulated by heat, and becomes insoluble. Insoluble in alcohol. Precipitated by infusion of nutgalls. Soluble in nitric acid.

12. *Fibrin*.—Tasteless. Insoluble in water and alcohol. Soluble in diluted alkalies and in nitric acid. Soon putrefies.

13. *Bitter principle*.—Colour yellow or brown. Taste bitter. Equally soluble in water and alcohol. Soluble in nitric acid. Precipitated by nitrate of silver.

14. *Extractive*.—Soluble in water and alcohol, insoluble in ether. Precipitated by oxymuriatic acid, muriate of tin, and muriate of alumina; but not by gelatine. Dyes fawn.

15. *Tannin*.—Taste astringent. Soluble in water

**Book IV.** and in alcohol of 0·810. Precipitated by gelatine, muriate of alumina, muriate of tin.

16. *Narcotic principle*.—Crystallizes. Sparingly soluble in hot water and alcohol.

17. *Fixed oils*.—No smell. Insoluble in water, alcohol. Form soaps with alkalies. Coagulated earthy and metallic salts.

18. *Wax*.—Insoluble in water. Soluble in alcohol, ether, oils. Forms soap with alkalies. Fusible.

19.—*Volatile oil*.—Strong smell. Insoluble in water, soluble in alcohol. Liquid. Volatile. Oily. nitric acid inflamed, and converted into resinous substances.

20. *Campbor*.—Strong odour. Crystallizes. Insoluble in water; soluble in alcohol, oils, acids; insoluble in alkalies. Burns with a clear flame, and volatilizes before melting.

21. *Bird-lime*.—Viscid. Taste insipid. Insoluble in water. Partially soluble in alcohol. Very soluble in ether; solution green.

22. *Resins*.—Solid. Melt when heated. Insoluble in water. Soluble in alcohol, ether, and alkalies. Insoluble in acetic acid. By nitric acid converted into artificial tannin.

23. *Guaiacum*.—Possesses the characters of resins but dissolves in nitric acid, and yields oxalic acid and no tannin.

24. *Balsams*.—Possess the characters of the resins but have a strong smell; when heated, benzoic acid sublimes. It sublimes also when they are dissolved in sulphuric acid. By nitric acid converted into artificial tannin.

25. *Caoutchouc*.—Very elastic. Insoluble in water and alcohol. When steeped in ether, reduced to a powder.

high adheres to every thing. Fusible and remains liquid. Very combustible.

26. *Gum resins*.—Form milky solutions with water, transparent with alcohol. Soluble in alkalies. With nitric acid converted into tannin. Strong smell, brittle, opaque, infusible.

27. *Cotton*.—Composed of fibres. Tasteless. Very combustible. Insoluble in water, alcohol, and ether. Soluble in alkalies. Yields oxalic acid to nitric acid.

28. *Suber*.—Burns bright and swells. Converted by nitric acid into suberic acid and wax. Partially soluble in water and alcohol.

29. *Wood*.—Composed of fibres. Tasteless. Insoluble in water and alcohol. Soluble in weak alkaline solution. Precipitated by acids. Leaves much charcoal when distilled in a red heat. Soluble in nitric acid, and yields oxalic acid.

But these are not the only substances which occur in the vegetable kingdom. It cannot be doubted that there are several others easily recognized by their peculiar properties in certain vegetable bodies; though chemists have not yet succeeded in obtaining them in a separate state, and in ascertaining their characters with precision. It was this deficiency of precise information that induced me to omit them; for nothing can be more hazardous than to swell the list of vegetable constituents, by introducing supposed substances from vague analogies and imperfect experiments.

There are many vegetable substances remarkable for peculiar acrid property. Most of the *ranunculi*, the *allygonum hydropiper*, *mustard*, &c. are well known instances. In some of these, the acridity disappears on drying, while in others, as *mustard*, it remains. In

Acrid principle.



Book IV.

some, as the ranunculi, the acrid portion is taken up by water; while in mustard water dissolves only a very small part, and acquires the taste of garlic. This acrid property certainly depends upon the presence of some principle or principles with which we are unacquainted.

We are equally ignorant of the nature of the peculiar liquid to which the leaves of the common nettle owe their property of irritating the skin. We do not know the substance which gives the alliaceous tribe their peculiar taste and smell; a substance amazingly penetrating, but which is destroyed or dissipated by the heat of boiling water. We know little of the narcous principle to which squills owe their virtues; and still less, if possible, of the poisonous juices with which many vegetables are filled. Indeed the only vegetable poison with which we can say we are acquainted is *prussic acid*. These are but a small number of instances, but abundance of others will occur to every reader. Indeed whole regions of the vegetable kingdom remain still unexplored. Much curious information may be expected from the analysis of the *fungi*, and other kindred plants; from the analyses of the *algæ*, and of the *lichens*. The last have indeed been examined by Hoffmann and Westring, but only with respect to their colouring matter.

Vegetable  
analysis  
imperfect.

Indeed the state of the chemical analysis of vegetables is still very imperfect. No general rules have yet been laid down; no successful method has yet been ascertained. In every particular case the analyst must follow his own judgment, and be guided by his own experience. Thus every one is obliged, in some measure, to invent a method for himself, and to create the whole as it were anew. Thus much time is wasted before the chemist is upon a level with his predecessors: and

ry one striking, as it were, from the same point, the progress is much slower than it otherwise would be.

The older chemists confined their analysis entirely to destructive distillation. By this process they obtained nearly the same products from every vegetable. Every plant when distilled yields water, oil, acid, carbureted hydrogen and carbonic acid gas; while a residuum of charcoal remains in the retort. For the introduction of solvents we are indebted to the alchemists. The experiments of Boerhaave and Newton were doubtless of value; but it was Rouelle who

made the great step in vegetable analysis, by pointing out the uses of various solvents to separate the different constituents of vegetables from each other. He was the first that attempted a precise description of the vegetable principles, and that gave marks by which their presence might be ascertained. The next great step was made by Scheele, who detected the different acids of vegetables, ascertained their properties, and pointed out the method of separating them from those vegetable substances into which they enter as constituents.

The experiments of some of the German chemists, especially of Hermstadt, added considerably to the discoveries of Rouelle and Scheele, and made us more acquainted with some of the constituents of vegetables. But of all the modern chemists none is entitled to greater praise than Vauquelin. His analyses have been numerous, and his discoveries important. He introduced into the subject that precision which distinguishes all his researches, and his method has been followed by all the other French chemists. Fourcroy has been often associated with Vauquelin, and his analysis of the quinquina, which he published alone, is en-

Improvements of  
Rouelle.

## • Book IV.

titled to very great praise. Proust has lately fixed his attention to the same subject, and has already favoured the world with very instructive papers. Lately the analysis of vegetable substances was almost entirely overlooked by British chemists; but the progress of the field has now begun to attract their attention. Experiments of great importance have been published by Davy, Chenevix, &c. and above all Hatchett, to whom vegetable chemistry lies under deep obligations; and we may expect still more important information from the zeal and skill of those enlightened philosophers. A few years will probably change the appearance of this branch of chemistry most entirely, and bring it nearer to the state in which the chemistry of minerals has already acquired.

Thus we have examined all the substances which have been hitherto examined from vegetables. In analysing each of them, or by exposing them repeatedly to destructive distillation, combustion, &c. we compare them last to those bodies which we are at present obliged to consider as simple, because they have not yet been compounded, and of which accordingly we must suppose that vegetables are ultimately composed. They amount to 15, namely,

Substances  
found in  
plants.

- |                  |              |
|------------------|--------------|
| 1. Oxygen        | 9. Manganese |
| 2. Sulphur       | 10. Potash   |
| 3. Phosphorus    | 11. Soda     |
| 4. Carbon        | 12. Lime     |
| 5. Hydrogen      | 13. Magnesia |
| 6. Azote         | 14. Silica   |
| 7. Muriatic acid | 15. Alumina  |
| 8. Iron          |              |

But of these substances there are twelve which compose but a very small proportion indeed of vegetables. Almost the whole of vegetable substances are composed of four ingredients, namely,

Carbon	Oxygen
Hydrogen	Azote

Of these the last, namely azote, forms but a small proportion even of those vegetable substances of which it is a constituent part, while into many it does not enter at all: so that, upon the whole, by far the greater part of vegetable substances is composed of carbon, hydrogen, and oxygen. I do not mention caloric and light; concerning the nature of which too little is known to enable us to determine with certainty into what substances they enter.

The substances at present known to chemists, which they have not been hitherto able to decompose, amount (omitting caloric and light) to about 47. Fifteen of these exist in plants; the rest belong exclusively to the mineral kingdom: for it is a fact, that no substance (I mean simple substance) has been hitherto found in the animal kingdom which does not exist also in vegetables.

On the contrary, all the simple substances at present known may be found in minerals. This indeed ought not to surprise us, if we recollect that the spoils of animals and vegetables, after they have undergone decomposition, are ultimately confounded with minerals, and consequently arranged under the mineral kingdom. Besides, if vegetables draw their food from the mineral kingdom, it would be absurd to suppose that they contain substances which they could not have procured from minerals.



---

---

**CHAP. II.****OF THE PARTS OF PLANTS.**  

---

---

**W**E have, in the preceding Chapter, enumerated and described the different substances hitherto detected in plants. But a more difficult task remains for the present Chapter ; namely, to explain the composition of each vegetable organ in all the numerous families of plants which constitute the vegetable kingdom. This task, indeed, in the present state of vegetable chemistry, cannot be fulfilled. By far the greater number of plants have never been examined at all ; and even of those which, from their medicinal virtues or nutritive qualities, have attracted the attention of chemists, only particular organs have been analysed, while the rest have been neglected as unworthy of notice. Nothing, therefore, either resembling a complete view, or an exact arrangement, is to be looked for in this Chapter. I shall satisfy myself with stating the most important facts hitherto discovered respecting the composition of plants, as far as I am acquainted with them, under the thirteen following heads :

- |                   |               |
|-------------------|---------------|
| 1. Sap            | 8. Seeds      |
| 2. Juices         | 9. Fruits     |
| 3. Wood and roots | 10. Bulbs     |
| 4. Bark           | 11. Lichens   |
| 5. Leaves         | 12. Mushrooms |
| 6. Flowers        | 13. Diseases  |
| 7. Pollen         |               |

Chap. II.

form the subjects of the following Sections.

## SECT. I.

### OF THE SAP OF PLANTS.

It is the general opinion of physiologists, that plants receive a considerable part of their nourishment by the sap; that it enters into them in a liquid state, and is carried up in proper vessels towards the leaves. This liquid is distinguished by the name of *sap*. In the spring, when the buds begin to expand themselves into leaves, if we break off the extremity of a branch, or make an incision into the wood of a tree, this sap flows out, and may be obtained in considerable quantities. It was first examined by Dr Hales; but chemical analysis had not made sufficient progress in his time to enable him to determine its constituents. Deyeux and Vauquelin have recently analysed the sap of different trees. To us we are indebted for most of the facts known respecting this liquid.

Definition.

The sap in all the vegetables hitherto examined is

Bank IV.  
Constitu-  
ents.

nearly as liquid as water. It always contains an acid, sometimes free, but more commonly combined with lime and potash. Various vegetable principles are also present: of these sugar is the most remarkable, and mucilage. Sometimes albumen and gluten, and sometimes tannin, can be detected. When left to itself, the sap soon effervesces and becomes sour; or even vinous, when the proportion of sugar is considerable.

Hitherto the sap of a few species of trees only has been examined. We are not in possession of any means of collecting the sap of the inferior orders of plants. The expressed juices of a considerable number of vegetables, indeed, have been prepared for medicinal purposes; but these are not sap, but a collection of all the liquid substances which the plant contained. At present, then, it is not possible to present a general view of the properties of sap. The following are the particular species which have been examined.

1. *Sap of the Elm, ulmus campestris.*

Vauquelin collected three different specimens of the sap of this tree; the first portion towards the end of April, the second in the beginning of May, and the third about the end of May. It had a reddish brown colour; its taste was sweet and mucilaginous; and it scarcely altered the colour of the infusion of litmus. Ammonia, barytes, and lime water throw down a copious yellow-coloured precipitate, which dissolves with effervescence in acids. Oxalic acid and the nitrate of silver throw down a white precipitate. Dilute sulphuric acid occasions a brisk effervescence, and disengages the odour of acetic acid. Oxymuriatic acid de-

destroys the colour of the sap, and throws down a brown precipitate. Alcohol produces a flaky precipitate. When evaporated by a gentle heat, a pellicle forms on the surface; brown flakes precipitate, and an earthy matter is deposited on the sides of the vessel. The earthy matter was a mixture of carbonate of lime and vegetable substance. The liquid, after depositing these bodies, and being evaporated to  $\frac{1}{10}$ ths of its original bulk, contained a considerable portion of acetate of potash.

1039 parts of this sap were composed, according to Vauquelin's analysis, of

1027·904 water and volatile matter

9·240 acetate of potash

1·060 vegetable matter

0·796 carbonate of lime

Constitu-  
ents.

The vegetable matter was partly extractive and partly mucilaginous\*.

On analysing the same sap somewhat later in the season, Mr Vauquelin found the quantity of vegetable matter a little increased, and that of the carbonate of lime and acetate of potash diminished. Still later in the season the vegetable matter was farther increased, and the other two ingredients farther diminished. The carbonate of lime was held in solution by carbonic acid, of which there existed a considerable excess in the sap. It is to this acid gas that the air bubbles, which so often accompany the sap as it issues from the tree, is owing†.

Changes of  
the sap by  
vegetation.

\* *Ann. de Chim.* lxxi. 20.

† See Coulomb, *Jour. de Phys.* xlix. 397.



## Book IV.

2. Sap of the Beech, *fagus sylvatica*.

## Properties.

Vauquelin collected two different specimens of this sap; the first in the end of March, the second about the end of April. It had a reddish brown colour, and a taste similar to the infusion of tan. It slightly reddened vegetable blues. Barytes, ammonia, carbonate of potash, and oxalate of ammonia, occasion precipitates in it; oxymuriatic acid throws down yellow flakes; sulphuric acid blackens it, and disengages the odour of acetic acid; sulphate of iron strikes a black, and glue throws down a copious whitish precipitate. When gently evaporated to dryness, it leaves a brown extract amounting to about  $\frac{1}{10}$  of its weight, ductile while hot, but brittle when cold, and having the smell and somewhat of the taste of new baked bread. It absorbs moisture from the atmosphere, and increases in weight about  $\frac{1}{4}$ th. Lime disengages ammonia, and sulphuric acid acetic acid, from this extract. Alcohol dissolves only a small part of it. This sap contained the following ingredients:

## Constituents.

Water  
 Acetate of lime with excess of acid  
 Acetate of potash  
 Gallic acid  
 Tannin  
 A mucous and extractive matter  
 Acetate of alumina

It contained, besides, a colouring matter, which may be fixed on cotton and linen by means of alum, and dyes them of a fine solid reddish brown colour\*.

---

\* *Ann. de Chim.* xxxi. 26.

3. *Sap of the Hornbeam, carpinus sykoestris* \*.

Properties.

Three specimens of this sap were collected by Vauquelin during the months of March and April. It was limpid, and its colour was whitish; its taste slightly sweet, and its smell analogous to that of whey. Barytes throws down from it a copious white precipitate, soluble in muriatic acid. Carbonate of potash likewise throws down a precipitate, soluble in acids with effervescence. Sulphuric acid deepens the colour, and evolves the odour of vinegar. Oxalic acid throws down a copious precipitate, and nitrate of silver gives the solution a fine red colour. 3918 parts, when distilled, left an extract of a reddish yellow colour, amounting to 8.279 parts. It had a sharp taste, and attracted humidity from the air.

When the extract is digested in alcohol, about the half of it dissolves. This portion consists of extractive, a saccharine matter, and acetate of potash. The residue, which is soluble in water, consists of mucilaginous matter, acetate of lime, and a colouring substance.

Action of the air.

When this sap was left exposed to the air in an open glass vessel, it became milky, disengaged carbonic acid, acquired a spirituous smell and taste, and its acidity increased. After some weeks this odour was dissipated, and carbonic acid was no longer extricated. Its acidity continued still to increase, white flakes fell to the bottom, and the liquid became transparent. After 50 days the acidity was found diminished, a mucous pel-

---

\* I presume the *carpinus betulus* is meant.

**Book IV.** licle formed on the surface, which became at last  
ish brown, and the liquid had only a mouldy taste. In  
a close bottle the sap never became transparent, and  
when the bottle was opened after three months, the  
air which it contained was found converted into carbonic  
acid and carbonic acid. The liquid had a very strong  
of vinegar\*.

4. *Sap of the Birch, betulus alba.*

**Properties.** The sap of this tree is colourless; it has a  
taste; reddens vegetable blues. Neither ammonia  
alcohol, nor oxymuriatic acid, produce any change  
it. Barytes and lime throw down a precipitate  
dissolves in muriatic acid. Hydrosulphurets, and  
of iron, and glue, produce no effect. Oxalic acid  
down a white precipitate. Sulphuric acid dis-  
the odour of vinegar. Nitrate of silver strikes  
colour. When evaporated to about  $\frac{1}{2}$ th, it leaves  
reddish brown powder insoluble in water. When  
parts of the sap were evaporated to dryness, they  
parts of brown extract. This had an agreeable  
attracted moisture from the atmosphere, and was  
most completely soluble in alcohol. When this  
**Fermented.** is dissolved in water and mixed with yeast, it ferments  
and the fermented liquor yields a considerable  
tion of alcohol; it yields also a considerable por-  
vinegar. Vauquelin did not succeed in his attempt  
obtain crystallized sugar from this sap; but he  
tained that it contained a portion of extractive  
dyes wool of a brownish yellow colour. Acc

---

\* *Ann. de Chim.* xxxi. 31.

lime and of alumina were also present, and probably  
 also acetate of potash \*. Chap. II

### 5. *Sap of the Yoke Elm.*

This sap has a bitter taste. When evaporated to dryness it leaves a brown extract, in which crystals of citrate of potash are gradually formed. This extract was scarcely soluble in alcohol. It gave traces of the presence of acetate of potash and acetate of lime †.

Such are the experiments made on sap by Vauquelin. All the saps examined contained acetic acid combined with lime and potash. Carbonate of lime with excess of acid was also sometimes present; and all of them contained some vegetable matter or other, which varied in its nature according to the plant from which it was extracted. The sap of the birch contained sugar, that of the beech gallic acid and tannin, and that of the elm and yoke elm, mucilage. Every sap contained also a portion of extractive, to which we may perhaps ascribe the ammoniacal odour emitted when the extract of these saps is burnt ‡. Much is still wanting before we can venture to draw any general inferences from these facts.

\* *Ann. de Chim.* xxxi. 36.

† *Ibid.* p. 38.

‡ I have not had an opportunity of seeing the dissertation of Deycux on this subject. He examined the sap of the vine and yoke elm, and discovered the acetates, and a matter which he compared to the curd of milk.



## SECT. II.

## OF THE PECULIAR JUICES.

Nature.

THE sap passes from the roots in peculiar vessels to the leaves, where it is altered by a process similar to that of digestion in animals, and formed into all kinds of liquid substances requisite for the purposes of the plant. These liquids flow from the leaves towards the appropriate vessels, and have received the name of *peculiar juices* of vegetables. They differ very considerably from each other in different plants. They all have a certain degree of consistency, and always contain much more vegetable matter than the sap. In the present state of vegetable chemistry, an accurate description of their properties cannot be attempted. Indeed it is difficult to procure them from many plants without the sap. They sometimes exude spontaneously, and may always be procured in smaller or greater quantity by incisions through the bark of the plants containing them. The following are the species of peculiar juices which have been hitherto attended to.

Milky  
juices.

1. *Milky juices*.—Many plants, when wounded, exude a considerable quantity of a milky liquid, which, in most cases at least, may be considered as one of the peculiar juices of the vegetable from which it flows. The nature of this juice is extremely various.

The root of the *campanula rotundifolia* yields a milky juice, of a peculiar, and not unpleasant smell and

Children in some parts of Scotland collect the plant for the sake of this juice, which they suck with avidity. Its chemical properties have not been examined.

Chap. II.

The different species of *euphorbia* yield a milky juice, which has a hot taste analogous to that of pepper, but more acrid, and which continues for a long time in the mouth. When oxymuriatic acid was poured into this juice, a very copious white precipitate fell down. This powder, when washed and dried, had the appearance of fine starch, and was not altered by keeping. It was neither affected by water nor alkalies. Alcohol, assisted by heat, dissolved two-thirds of it; which were precipitated by water, and had all the properties of resin. The remaining third part possessed the properties of the *woody fibre*. Mr Chaptal tried the same experiment on the juices of a great number of other plants, and he constantly found that oxymuriatic acid precipitated from them *woody fibre*.\*

Euphorbia.

The different species of the poppy (*papaver*) and lettuce (*lactuca*) yield a milky juice, which possesses narcotic qualities, and is distinguished by a peculiar taste and smell. These juices have been more examined than the preceding. They are of a very complex nature, containing a great variety of constituents. Gum and resin, and extractive, are the most prominent of these; and if the experiments of Derosne concerning the peculiar narcotic principle which he detected in opium, and which have been detailed in the preceding Chapter, be confirmed, we must consider that principle as constituting an essential ingredient in these juices.

Poppy.

\* *Ann. de Chim.* xxi. 285.

**Book IV.**  
**Caoutchouc.** The milky juice which exudes from the *jatropha elastica*, the *hevea caoutchouc*, the *artocarpus integrifolia*, the *urceola elastica*, and from several other plants gradually becomes inspissated when exposed to the air and constitutes caoutchouc. This juice has been hitherto examined only by Fourcroy. Though kept in close vessels, the caoutchouc for the most part gradually separates, and forms a white solid elastic mass. The juice, however, still continues milky. When evaporated in the open air, a pellicle of caoutchouc gradually forms on the surface, and when this is removed another succeeds. Fourcroy ascribes this formation to the absorption of oxygen from the atmosphere. Besides the caoutchouc, Fourcroy obtained from the juice transparent prismatic crystals, which had a sweet taste and which he considered as saccharine matter approaching to the nature of an acid\*.

**Papaw.** The juice of the papaw tree possesses properties which distinguish it from most others. According to the analyses of Vauquelin, detailed in the preceding Chapter, its constituents resemble very closely the constituents of blood.

Besides the milky juices enumerated above, there are many others. Almost all the gum resins indeed are originally in that state; but as no chemical analysis of these juices has yet been made, it is needless to dwell upon them†.

**Mucilaginous juices.** 5. *Mucilaginous juices.*—The peculiar juices of man

---

\* *Ann. de Chim.* xi. 225.

† The reader may consult a dissertation on the milky juices of plants by Carradori. See *Gehlen's Jour.* vi. 630.

plants are not milky, and some not distinguished by any strong taste or smell. In these mucilage seems to be the predominating matter. Under this head may be reckoned the juices of most of the mucilaginous plants enumerated in the fifth Section of the preceding Chapter.

Chap. II.

The substance called *cambium*, too, if we may be allowed to consider it as a peculiar juice, since it is obviously different from the sap, is entirely mucilaginous. It makes its appearance, according to Mirbel, in all those parts of vegetables where new matter is to be formed, and seems necessary for all such formations, either as the matter employed in their formation, or as furnishing a proper bed for them to be formed in. It does not appear to be confined in vessels like the other juices \*.

Cambium.

3. Some juices are intermediate between volatile oils and resins. These may be distinguished by the name of *turpentine*. Common turpentine, balsam of copaiva, and probably also opobalsamum, belong to this class. These juices are originally limpid and transparent, have a strong smell and taste, and gradually acquire consistency by exposure to the air, probably by absorbing oxygen.

Turpentine.

4. Other juices obtained by excision possess at first the properties of resins, or at least acquire them before they are brought into this country. Such, for example, are tacamahac and mastich, and most of the resinous bodies described in Section XXIII. of the preceding Chapter.

Resins.

5. Others are entitled to the name of *balsam*, accord-

Balsams

\* Mirb.l, *Ann. de Mus. d'Hist. Nat.* No xl. p. 294.



Book IV.

ing to the strict meaning of the word ; as balsam of tolu of Peru, styrax, and benzoin.

Tannin.

6. Some peculiar juices are composed almost entirely of tannin, or at least are characterised by containing a superabundance of that substance. Such probably are the juices of oak, sumach, and of most vegetables that yield abundance of the tanning principle. In some cases, it would seem that these juices exude spontaneously ; though in general they are obtained by artificial means.

Sugar.

7. Some vegetables possess juices characterized by the great quantity of sugar which they contain. Such for example, as the sugar-cane, the carrot, and the various species of beet. For it is surely more reasonable to consider the saccharine matter in these plants as belonging to the peculiar juices than as confined to the sap.

Saline matter.

8. Finally, the peculiar juices of some plants are characterized by containing a considerable proportion of saline matter. Thus the various species of sorrel contain a notable quantity of superoxalate of potash, and several of the sedums malate of lime. In short, the peculiar juices of plants are nearly as numerous as the vegetable principles themselves ; and when the fungi, algæ, lichens, and several other of the numerous inferior tribes of vegetables have been once examined, cannot be doubted that the number will greatly increase.

Braconnot has lately examined the juices of a number of plants, in order to ascertain the peculiar acids which

obtained. The following is a short abstract of  
 its which he obtained \*. Chap. II.

expressed juice of the *aconitum lycortomum* eva-  
 to dryness and inciperated leaves about 0.01 of  
 e of potash. This juice contains a considerable  
 on of citric acid, partly combined with potash  
 ly with lime. Perhaps also malic and acetic  
 : present in the juice of this plant.

juice of the *delphinium elatum*, the *ranunculus*  
*lius*, the *thalictrum flavum*, the *clematis recta* and  
 , likewise contains a quantity of citric acid like  
 eding juice.

juice of the *salvia sclarea* contains benzoic acid  
 r combined with potash.

juice of the *ruta graveolens* contains malic acid  
 d with potash and with lime.

juice of the *eupatorium cannabinum* contains an  
 ich appears to be the malic mixed with some  
 ric.

juice of the *nicotiana rustica* and *tabacum* con-  
 dic acid combined with potash and lime.

juice of the *mirabilis jalapa* contains nitric acid,  
 : acid, malic acid, and a little sulphuric acid  
 combined with potash.

*spinacia oleracea* contains oxalates of lime, and  
 h, malate and phosphate of potash.

*tropaeolum majus* contains phosphoric acid, nitric  
 d malic acid united to lime and to potash.

*ricinus communis* contains malic acid doubtless  
 ed with potash.

\* *Ann. de Chim.* lxx. 277.

Book IV.

The *phytolacca decandra* contains an uncommon proportion of potash, and an acid which possesses the properties of the oxalic.

---



---

### SECT. III.

#### OF THE WOOD AND ROOTS.

THE roots of a great variety of plants are employed in medicine and the arts ; but few of them have been hitherto subjected to chemical examination. The substances found in them are various ; and indeed, as the peculiar juices of the roots are always included in such examinations, it is clear that almost all the vegetable principles will be found in them.

The process usually followed in examining these substances, is first to separate every thing soluble in cold water, then to boil the root in water. Alcohol is applied next ; and afterwards different acids or alkalies, according to the nature of the substances suspected to be present. The roots of the following plants have been subjected to chemical examination :

List.	Helleborus hyemalis	Convolvulus jalappa
	Brionia alba	Gentiana lutea
	Calaguala	Rheum palmatum
	Ho-ang-lien	Rubia tinctorum
	Cephælis, or calicocca	Curcuma longa
	ipecacuanha	Valeriana officinalis

*Helleborus hyemalis*.—The root of this plant is tuberous, has a yellowish white colour, and is covered with a black skin. At first it has no taste; but in a short time a strong acridity becomes sensible in the mouth and throat. Vauquelin has lately subjected it to chemical examination, chiefly in order to ascertain the nature of the bitter and acrid principle which it contains. This principle he found to be an oil of a peculiar nature, possessing properties intermediate between fixed and volatile oils. He obtained it by digesting the root in alcohol, and then distilling off the alcohol in a vacuum. The oil gradually separated and concreted on cooling. Its taste was extremely acrid, and it had a yellowish brown colour. When dissolved in weak alcohol, it precipitates the sulphates of iron of a fine purple colour, which becomes green by means of alkalis. This oil is extremely poisonous, and, according to Vauquelin, exists in many plants, and is the cause of their poisonous qualities.

Chap. II.

*Helleborus hyemalis*.

Contains a poisonous oil.

When the root is digested in water, and the liquid passed through a cloth, it is obtained opaque and milky, and gradually deposits a white powder which possesses the properties of starch. The liquid, by evaporation, leaves a brownish matter, which forms successive layers on the surface. This substance possesses the properties of extractive. Besides these substances, Vauquelin detected a substance analogous to gluten, sugar, and a portion of woody fibre\*.

2. *Prionia alba*.—This root has been used in medicine, and was known to contain a considerable portion

*Prionia alba*.

---

\* *Ann. de Mus. d'Hist. Nat.* No. 3888. 22.



Book IV.  


Constitu-  
 ents.

Calaguala.

of starch, and a bitter principle soluble in water and alcohol. Vauquelin lately examined it. By infusion in water, and subsequent pressure in a linen cloth, the starch was separated and obtained in a state of purity. The bitter substance was soluble both in water and alcohol, and appeared to possess the properties of a pure bitter principle. The root was found like the others to contain a considerable portion of gum; a substance which is precipitated by infusion of galls, and Vauquelin denominates *vegeto-animal matter*. It also contains woody fibre, a small portion of sugar, and a quassia supermalate of lime and phosphate of lime\*.

3. *Calaguala root*.—This is a root brought from America for medicinal purposes, which has acquired a considerable celebrity on the continent. The place from which it is obtained is not known; but from the observations of Vauquelin is supposed to be a species of *polypodium*. It has a brown colour, is partly covered with scales like the roots of fern, and is very hard and difficult to reduce to powder. Vauquelin, lately subjected it to analysis, found it a very complex substance, and separated from it no fewer than the following substances:

Constitu-  
 ents.

Woody fibre	Colouring matter
Gum	Malic acid?
Resin	Muriate of potash
Sugar	Lime
Starch	Silica

Alcohol dissolves the resin and sugar. By evap

---

\* *Ann. de Mus. d'Hist. Nat.* No. xliij. 82.

the solution to dryness, and treating the residue with water, the sugar is separated and the resin left. This resin has a reddish brown colour, and a bitter and acrid taste. It dissolves in alkalies, communicating a brown colour and a bitter taste, and is again separated by acids. Vauquelin suspects that this principle is the constituent of the root, both of this plant and of the other filices which possess vermifuge properties. Water dissolved the gum and the muriate of potash, which were obtained by evaporation. Diluted nitric acid dissolved the starch and the colouring matter, and let fall the former when mixed with four times its bulk of alcohol. The woody fibre remained, which when incinerated left carbonate of lime, muriate of potash, and a little silica. As the decoction reddened vegetable blues, it is possible that the lime was in combination with malic acid \*.

4. *Ho-ang-lien*.—This is a bitter tasted root, brought from China, and used on the continent as a medicine. It has been slightly examined by Bouillon la Grange. From his experiments, it seems to owe its properties chiefly to the bitter principle, of which it contains a considerable portion. It contains also a resinous matter, taken up by alcohol and thrown down by water. This substance when dry has a brown colour, melts when heated, and burns, emitting an aromatic odour †.

Ipecacuan

5. *Ipecacuan*.—This is the root of a plant which grows spontaneously in Brazil, and probably in other parts of South America. It was first correctly described and figured by Dr Brotero, under the name of *cal-*

\* Vauquelin, *Ann. de Chim.* iv. 22.

† Ibid. p. 40.

Book IV.

*Licocca ipecacuanba* \*. The root is about the thickness of a quill, unequal and knotty, and varies considerably in its colour. When pounded it forms the mass and safest emetic in the whole *Materia Medica*. It was probably employed in America from time immemorial; it was not introduced into Europe till the time of 1614, when one Grenier, a French merchant, brought 150lbs. of it from Spain; with which trials were made at the Hotel Dieu. Helvetius first made known its use in dysentery, for which he was rewarded by Louis XIV. with L. 1000 sterling †.

Properties.

This substance, notwithstanding its importance in medicine, has not hitherto been subjected to an accurate chemical examination. The most recent experiments are those of Dr Irvine, who gained the prize of the Herveyan Society, at Edinburgh, for the year 1781. From his experiments, it appears to contain a gummy resinous matter, in which its activity chiefly resides. Probably, also, pure resin and extractive are to be found in it. When the root is long boiled in water, its activity is destroyed. When distilled along with water the liquid that comes over is inactive; but the distillation which remains in the alembic acts with violence upon the system.

Jalap.

6. *Jalap*.—This very active cathartic is the root of the *convolvulus jalappa*, a plant which is a native of Xalapa, a province of New Spain ‡. It is brought into Europe in thin slices, which are hard, of a brown colour, exhibiting resinous streaks and circles, easily

\* *Linnean Trans.* vi. 132.† Neumann's *Chem.* p. 357.‡ Hence the term *Jalap*. Neumann's *Chem.* p. 352.

flammable, of scarcely any smell, and a weak acrid taste. The chemical nature of this root has not been much examined. From the few experiments detailed by Neumann, it appears to contain a resin, to which its active properties are ascribed, and likewise a portion of extractive and of mucilaginous matter. Chap. II.

7. *Rhubarb*.—This is the root of the *rheum palmatum*, and perhaps also of some other species of *rheum*, brought chiefly from the northern parts of China by the way of Russia, though of late it has been cultivated also in Britain. The root is large, of an oblong or roundish shape; of a dark brown colour externally, with black and reddish streaks; internally it is reddish yellow, and when fresh contains a juice of the same colour. No accurate chemical analysis of rhubarb has yet been made; but from the experiments of Neumann, it appears that nearly one half of it is soluble in water, and that alcohol scarcely takes up any thing from the residue. From the properties of the watery extract, enumerated by that laborious chemist, we may infer, with some probability, that it consists chiefly of the extractive and bitter principle, and that it contains some tannin. A small quantity of greenish yellow resinous matter seems also to be present\*. Scheele separated from the root about  $\frac{1}{6}$ th of its weight of oxalate of lime†. But this salt is not taken up by water. Rhubarb.

8. *Gentian*.—This is the root of the *gentiana lutea*, a plant which grows spontaneously in the mountainous parts of France, Switzerland, Hungary, &c. It is said Gentian.

\* Neumann's *Chem.* p. 360.

† Crell's *Annals*, i. 34. Engl. Transl.



## Book IV.

to have been named after Gentius, a king of Illyria, who is supposed to have first discovered its virtues. The root is externally brown; internally yellow, with a spongy pith in the middle. Its taste is intensely bitter. From the experiments of Neumann, we may conclude that the soluble parts of it consist chiefly of bitter principle, mucilaginous matter, resin, and extractive. The first seems to be the most copious and most active ingredient, and the one to which it owes its medicinal properties.

## Madder.

9. *Madder*.—This is the root of the *rubia tinctorum*, a plant cultivated in Zealand, &c. for the dyers. The root is the useful part, forming one of the most valuable of the red dyes. It is about the thickness of a goose quill, somewhat transparent, of a reddish colour, and a strong smell. The colouring matter of madder is the only part of this root that is valued. Mr Watt has published a dissertation on it; to which we owe almost every thing that we know respecting its chemical nature.

## Properties.

It appears that there are two distinct colouring matters in madder: a red, which is extracted readily by cold water; and a brown, which requires a boiling heat to separate it in any quantity. Hence the reason that dyers are cautious not to raise the infusion of madder to a boiling temperature till towards the end of their process. Both of these colouring matters appear to possess the properties of extractive. They are soluble in water and alcohol; and when the solution is evaporated, pellicles successively form on the surface. These gradually subside, and form a reddish brown matter only imperfectly soluble in water. When alum liqu...

is poured into the infusion of madder, a deep brownish red flaky precipitate falls, and the liquid assumes a brownish yellow colour; and alkaline carbonates and lime water throw down a blood red lake, differing in the shade of its colour according to the proportion of alum employed. Acetate of lead throws down a brown-coloured precipitate.

When carbonate of magnesia is mixed with infusion of madder, the liquid assumes a bright blood-red colour; and by evaporation an extract is obtained, which readily dissolves in water, and when spread upon paper becomes yellow in a few days, if exposed to the sun.

Water, holding a little alkali in solution, forms with madder a dark brownish red solution; but if the water be mixed with a little acid, the infusion is yellowish\*.

From the late observations of Merimé, it appears probable that a third colouring matter is present in madder; that it is more soluble than the red; and that it may be separated by steeping the madder a certain time in water, and then precipitating the solution with an alkali. After this a much finer red lake may be obtained from madder†.

10. *Turmeric*.—This is the root of the *curcuma longa*, Turmeric. a plant which grows in the East Indies. It has a fine yellow colour, a slight smell, and an aromatic bitter taste. To water it gives its own yellow colour, and the infusion is rendered brown by alkalies. To alcohol it gives a red colour, which stains hot marble of a durable colour‡. The constituents of this root are but

\* See Watt, *Ann. de Chim.* iv. 104.

† Berthollet, *Elements de l'Art de la Teinture*, ii. 120.

‡ Lewis, *Neumann's Chem.* p. 384.

Book IV.

imperfectly known. From the experiments of Newmann, we learn that it contains a little volatile oil; the water dissolves nearly one-third of the root, but that very small portion only is soluble in alcohol\*. It forms the chief ingredient in *curry powder*.

Valerian.

11. *Valerian*.—Trommsdorf has examined the root of the *valeriana officinalis*. It loses three-fourths of its weight by drying. Distilled with water it yields volatile oil, very liquid, and of a greenish white colour. Its odour is strong and camphoric; its specific gravity at the temperature of 77°, is 0.9340; its taste is aromatic and camphoric without being acrid. When exposed to the light it becomes yellowish. Nitric acid converts it into a resinous substance, or, if it be used in a sufficient dose, into oxalic acid. The expressed juice of the roots of this plant is muddy, and has a strong odour. It lets fall a portion of starch. It contains a peculiar substance approaching the nature of extractive, soluble in water, but insoluble in ether, and in pure alcohol. It is precipitated from water by the salts of lead, silver, mercury, and antimony. This juice contains also a portion of gum. The roots deprived of the juice yield a portion of black coloured resin, but consist chiefly of woody fibre†.

Horse radish.

12. *Horse radish*.—Einhoff has lately examined the root of this vegetable, and found that its acridity is owing to the presence of a small quantity of volatile oil, which he obtained by distilling the mashed roots in water bath. A liquid came over which was at first milky, but gradually deposited a little of the volati

\* Lewis, Neumann's *Chem.* p. 388.† *Ann. de Chim.* lxx. 92

oil in question. This oil had a pale yellow colour, and the consistence of the oil of canella. Its odour was that of horse radish excessively strong. Its taste was at first sweetish; but it left an acrid impression, and excited inflammation in those parts of the tongue and lips to which it was applied. It is heavier than water, with which it forms a milky liquid by agitation. It dissolves readily in alcohol. It is volatilized at the temperature of 60°. The liquid obtained from the roots of the horse radish by distillation yielded traces of sulphur\*.

Chap. II.

Many other roots have been employed either in medicine or the arts; but as they have not yet been subjected to chemical analysis, I think it unnecessary to enumerate them here. For the same reason, out of the vast number of woods known and employed in the arts, I shall mention only the following:

1. *Logwood*.—This is the wood of the *bæmatoxylon campechianum*, a low prickly tree, which grows abundantly about Campeachy, on the bay of Honduras. It comes to Europe in large logs, cleared from the bark, and is very hard, compact, heavy, and of a red colour. It has a sweetish astringent taste, but no perceptible smell. It is very much used by dyers, especially in dyeing black, to which indeed it is in some degree essential. For the facts known respecting its properties, we are chiefly indebted to Dr Lewis†. Several of its constituents have lately been ascertained by Chevreul‡.

Logwood.

Logwood gives out its colouring matter both to wa-

Properties.

\* *Ann. de Chim.* lxx. 185.

† *Neumann's Chem.* p. 385.

‡ *Ann. de Chim.* lxxvi. 254.



Book IV.

ter and alcohol; but to neither with much. The liquors assume a fine red colour with a purple. The infusion becomes gradually deep at last almost black. To cloth, previously be alum and tartar, it gives a very beautiful, but able violet colour. Alkalies deepen the colour infusion; acids change it to yellow. With nitric, muriatic, and acetic acids, slight reddish precipitates fall. Alum throws down a copious precipitate. Sulphate of iron strikes a dark black like ink, and throws down slowly a precipitate of the same colour. Sulphate of copper throws down a copious brownish black precipitate, and acetic acid an equally copious reddish black precipitate. Muriate of tin throws down instantly a copious precipitate, while the liquid becomes transparent and less \*. Chevreul has shown that this wood contains volatile oil, tannin, a yellow colouring matter, a state of lime and of potash †.

Brazil wood.

2. *Brazil wood*.—This is the wood of the *caecilia*, a tree which grows in Brazil, and like other countries, where it is cultivated for the dye. The tree is very large, and the wood very hard and very heavy. Its colour is at first whitish, but becomes red by exposure to the air. Water in which it is boiled acquires a fine red colour; while the wood itself, by repeated decoctions, becomes black. After it has ceased to act, alkaline leys still deprive it of a considerable quantity of colouring matter.

---

\* Berthollet, *Elements de l'Art de la Teinture*, ii. 244.

† *Ann. de Chim.* lxi. 254.

likewise takes up the colouring matter of Brazil wood, and acquires a deeper colour than water. Chap. II.

From the decoction in water, sulphuric and muriatic acids throw down a scanty red precipitate, while the liquid becomes yellow. An additional dose of acid restores the red colour again. Nitric acid changes it to yellow, and then to orange. Oxalic acid throws down an orange red precipitate. The alkalies change the colour to purple, and throw down a scanty precipitate. Alum precipitates slowly a copious reddish lake, and muriate of tin an abundant rose-coloured powder, while the liquid becomes nearly colourless. Sulphate of iron strikes a black with a tint of violet, and throws down a precipitate of the same colour. Acetate of lead throws down a fine dark red precipitate\*. An elaborate set of experiments on Brazil wood has lately been published by Chevreul. The following are the results which he obtained :

The decoction of yellow Brazil wood is yellow. Properties.  
When distilled it yields water containing a portion of acetic acid, and a volatile oil having the odour and taste of pepper. As the liquid is concentrated by evaporation, a viscid matter is perceptible, of a brown colour, which is a compound of tannin and the colouring matter. The liquid retains a portion of the same substances. It contains also traces of ammonia, and of lime probably combined with acetic acid. Chevreul suspects also the presence of sugar and of gallic acid ; both of which he detected in the extract of Brazil wood of commerce. All his attempts to separate the colour-

---

\* Berthollet, *Elémens de l'Art de la Teinture*, ii. 229.

Book IV.

ing matter from tannin, and obtain it in a separate form. The acids change it from yellow to red in infusions containing it. Alkalies and alkalis make it pass to violet. Alumina strikes a deutoxide of tin a violet, and peroxide of tin a blue. Several neutral salts, as sulphate of iron, when added in considerable quantity, change it to red. Sulphureted hydrogen gas combines with it and destroys the colour; but it appears again when sulphureted hydrogen is separated. It has more affinity for alkalies than litmus; and accordingly renders litmus paper red, by depriving it of the colour with which it is in combination\*.

Red sanders.

9. *Red sanders*.—This is the wood of the *Santalum album*, a large tree which grows on the Malabar coast, and in other parts of India. It is at first light red, but becomes very dark by exposure to the air. It is very compact and ponderous, has no smell, and very little taste. This wood is used for colouring drugs, and has not yet been subjected to chemical examination. The colouring matter is of a resinous nature, and probably similar to dragon's blood. It is taken up by alcohol, but not by water. The alcoholic tincture is a fine red, which becomes yellow when diluted with a large quantity of spirits†. By this property of yielding no colour to water, we can easily distinguish red sanders from Brazil wood; a distinction first pointed out by Lewis‡.

\* *Ann. de Chim.* lvi. 225.† *Neumann's Chem.*‡ *Ibid* p. 336.

4. *Fustic*.—This is the wood of the *morus tinctoria*, Chap. II.  
 a large tree which grows in the West India islands. It Fustic.  
 is used in dyeing yellow, and is very rich in colouring  
 matter. It is neither very hard nor heavy; its colour  
 yellow with orange veins. It gives a deep orange  
 colour to water. The decoction gives a precipitate  
 with glue, but still retains its colour. Acids throw  
 down a slight greenish yellow precipitate, which is re-  
 dissolved by alkalis. These give the decoction a dark  
 red colour, and gradually separate a yellowish matter.  
 Alum throws down a scanty yellow precipitate; sul-  
 phate of iron, a precipitate at first yellow, but which  
 becomes brown; sulphate of copper, a yellowish brown  
 precipitate; acetate of lead, an orange yellow precipi-  
 tate; and muriate of tin, a very copious fine yellow  
 precipitate\*.

5. *Sumach*.—This is the shoots of the *rubus coriaria*, Sumach.  
 a shrub which grows in the countries bordering on the  
 Levant. They are cut down yearly, dried, and ground  
 in a mill. Like the preceding substances, it is used in  
 dyeing, and chiefly as a mordant, on account of the tan-  
 nin which it contains. It gives to water a greenish  
 yellow colour, which soon becomes brown by exposure  
 to the air. It has not yet been subjected to a regular  
 chemical analysis. The tannin appears to be the prin-  
 cipal ingredient; and, according to Proust, it differs in  
 its properties from the tannin contained in other plants.  
 Bartholdi published a set of experiments on the decoc-  
 tion of this plant. According to him, it contains a  
 great variety of saline matters; nitrate of potash, mu-

\* Berthollet, *Elémens de l'Art de la Teinture*, II. 259.



Book IV. { riate of soda, sulphate of lime, gallate of magnesia, carbonate of lime, &c. But these experiments stand in need of repetition \*.

---

## SECT. VI.

### OF BARKS.

Bark.

Consists of  
three sub-  
stances.

1. Epider-  
mis.

THE bark is the outermost part of vegetables. It covers the whole plant from the extremity of the roots to the extremity of the branches. It is usually of a green colour: if a branch of a tree be cut across, the bark is easily distinguished from the rest of the branch by this colour. If we inspect such a horizontal section with attention, we shall perceive that the bark itself is composed of three distinct bodies, which, with a little care, may be separated from each other. The outermost of these bodies is called the *epidermis*, the middlemost is called the *parenchyma*, and the innermost, or that next the wood, is called the *cortical layers*.

The *epidermis* is a thin transparent membrane, which covers all the outside of the bark. It is pretty tough. When inspected with a microscope, it appears to be composed of a number of slender fibres crossing each other, and forming a kind of net-work. It seems ever

---

\* *Ann. de Chim.* xii. 305.

to consist of different thin retiform membranes, adhering closely together. This, at least, is the case with the epidermis of the birch, which Mr Duhamel separated into six layers. The epidermis, when rubbed off, is reproduced. In old trees it cracks and decays, and new epidermes are successively formed. This is the reason that the trunks of many old trees have a rough surface.

The *parenchyma* lies immediately below the epidermis; it is of a deep green colour, very tender, and succulent. When viewed with a microscope, it seems to be composed of fibres which cross each other in every direction, like the fibres which compose a hat. Both in it and the epidermis there are numberless interstices, which have been compared to so many small bladders.

2. The parenchyma.

The *cortical layers* form the innermost part of the bark, or that which is next to the wood. They consist of several thin membranes, lying the one above the other; and their number appears to increase with the age of the plant. Each of these layers is composed of longitudinal fibres, which separate and approach each other alternately, so as to form a kind of network. The meshes of this network correspond in each of the layers; and they become smaller and smaller in every layer as it approaches the wood. These meshes are filled with a green coloured cellular substance, which has been compared by anatomists to a number of bladders adhering together, and communicating with each other.

3. The cortical layers.

Foucroy supposes that the epidermis is the same in its nature in all trees, and that it possesses constantly the properties of suber; but this opinion is not likely to be verified. The cortical layers seem, at least in

Nature of barks.

Book IV.

many cases, to have a similar fibrous basis; a basis possessing essentially the properties of flax, which is itself merely the cortical layers of the *linum usitatissimum*. The matter of the parenchyma, and the juices which exist in barks, vary extremely, and probably occasion most of the differences between them. Some, as oak bark, are characterized by their astringency, and contain tannin; others, as cinnamon, are aromatic, and contain an essential oil; others are bitter, as Jesuit bark; some are chiefly mucilaginous, others resinous, &c. But in the present state of the subject, an enumeration of the different kinds of barks is not to be expected. I shall therefore, as in the preceding Sections, satisfy myself with detailing the properties of those barks that have been subjected to examination. The following are the most remarkable of these:

Quinquina  
of St Do-  
mingo.

1. *Bark of the cinchona floribunda*, or *quinquina of St Domingo*.—This bark has been analysed with great address by Fourcroy. His analysis still constitutes one of the completest which has hitherto been made on any of the substances belonging to the vegetable kingdom.

This bark is in rolled pieces, six or seven inches long, and three or four lines in thickness. Its colour is greyish green externally, but within it exhibits different shades of green, purple, white, brown, &c. Its taste is bitter and disagreeable; its odour strong and unpleasant.

It gives out nearly half its weight to water, provided it be boiled in a sufficient quantity of that liquid. The residue possesses the properties of woody fibre. When burnt it leaves a coal, which contains the follow-

ing saline constituents. The quantities are those obtained from a pound, or 9216 grains of the bark.

Chap. II.

Carbonate of potash ..... 10 grains

Earthy residue.

Sulphate of potash ..... 12

Muriate of potash ..... 38

Phosphate of lime ..... 20

Carbonate of lime ..... 420

Silica ..... 4

The decoction of the bark has a reddish brown colour, and an extremely bitter taste. It deposits on cooling a blackish substance, soft and tenacious, which does not dissolve in cold water, though it is soluble in hot water and in alcohol. More of this substance precipitates as the liquor is evaporated. When the inspissated juice, freed from this precipitate, is mixed with alcohol, a quantity of gummy matter separates. When the black matter which precipitates as the decoction cools is treated with hot alcohol, the greatest part of it is dissolved; but a fine red powder remains mixed with some mucilage, which is easily separated by water. When the alcoholic solution is exposed to the air, it deposits light yellowish crystals of a saline nature. When mixed with water, white flakes are thrown down, which possess the properties of gluten; but the greatest part remains in solution. Thus the soluble part of the bark may be separated into five distinct substances; namely, *gum*, *gluten*, a *red powder*, a *saline matter*, and a *brownish bitter substance*, retained in solution by the diluted alcohol. The last is by far the most abundant. To it the peculiar qualities of the decoction of this bark are to be ascribed. The following are the quantities obtained by Fourcroy from 9216 grains of the

Matter soluble.



Book IV.

Gum.....	548 grains
Gluten.....	84
Red powder.....	144
Saline crystals.....	72
Brownish matter ...	4076

---

Total 5024

**Properties.** The gummy matter and gluten possessed very nearly the properties of these substances, as described in the last Chapter of this work. The red powder is insoluble in water and alcohol, but dissolves readily in alkalis. When distilled it yields much oil and ammonia and little water. According to Fourcroy, it is *extractive* saturated with oxygen. The nature of the saline matter was not determined in a satisfactory manner. The brownish matter which remained dissolved in the diluted alcohol, being by far the most abundant and important ingredient, was examined with particular care. From the experiments of Fourcroy, it appears to approach nearest to *extractive* in its properties.

Its colour is reddish brown, and its taste very bitter. When dry it appears black, is very brittle, and breaks with a vitreous fracture. It is insoluble in cold water, but dissolves very readily in that liquid when heated, precipitating, however, in part, as the water cools. But if one part of it be dissolved in 24 parts of hot water, no portion of it precipitates. If lime water be dropped into this solution, it throws down a reddish powder, redissolved by the addition of a sufficient quantity of water. Muriaic acid precipitates nothing from this solution. The brown matter dissolves readily in alcohol, if it be previously reduced to powder. When distilled it gives out carbonic acid and inflammable air.

water impregnated with pyromucous acid, and a quantity of oil. The watery portion contains likewise ammonia. The charry residue is very bulky, ten times as much so as the original matter.

When oxymuriatic acid gas is passed through this extractive substance dissolved in water, it becomes immediately reddish, and then a precipitate of the same colour gradually falls. This precipitate possesses exactly the properties of the *red powder* obtained from the decoction of the bark; a proof that this red powder is merely the brown extractive altered in its properties by the absorption of oxygen. If the current of oxymuriatic gas be continued, the whole liquor gradually loses its colour, and the precipitate also becomes a pale yellow. If it be separated in this state by filtration, it assumes the appearance of gamboge. Alcohol dissolves it, but not a mixture of alcohol and water\*.

2. *Bark of cinchona officinalis*.—This tree grows in Quito; it is confined to the high grounds, and when stripped of its bark soon dies. There are three different kinds of *bark* to be found in commerce, but whether they be all obtained from the same trees is not known; the contrary is probable. The following are the most remarkable of these varieties.

Peruvian  
bark.

*Red Peruvian bark*.—This bark is usually in large pieces, and is reducible to powder with more ease than the preceding. Its powder is reddish brown, and has a slightly bitter taste, with a good deal of astringency. We are indebted to Fourcroy likewise for the analysis of this bark.

1. Red.

\* Fourcroy, *Ann. de Chim.* viii. 120.

Book IV.

Water in which the powdered bark is macerated, acquires the property of reddening vegetable blues, and contains a portion of citric acid, some muriate of ammonia, and muriate of lime. When 576 parts of the bark are boiled repeatedly in water till that liquid ceases to have any action on it, the water acquires a reddish orange colour, and when evaporated to dryness leaves a residue which amounts to 38 parts. This contains a small portion of the acid and salts just mentioned, but consists chiefly of a matter which possesses nearly the properties of extractive. When the residual bark is treated with a sufficient quantity of alcohol, that liquid takes up 24 parts of a substance which has a red colour, and appears intermediate between resin and extractive. The residue of the bark possesses the properties of woody fibre. When burnt it leaves twelve parts of a grey ash, consisting of

Carbonate of potash .....	1.9
Muriate of potash, .....	0.6
Sulphate of potash .....	0.5
Carbonate of lime .....	9.0

---

12.0

Such is the result of Fourcroy's analysis \*. Subsequent experiments have detected a portion of resin and of bitter principle. The presence of tannin in small quantity was indicated by the property which the decoction showed of striking a black with sulphate of

---

\* *Ann. de Chim.* viii. 174.

The bitter principle seems to belong to the same species, or that which was first observed in coffee. *Yellow Peruvian bark.*—This species of bark, first brought into use in this country about the year 1790, has not yet been subjected to a rigorous analysis; but its constituents do not appear, from the trials which have been made, to differ much from those of the red species. Deschamps has published a method of extracting from it a considerable quantity of an undescribed salt, the base of lime, which Vauquelin has shown to be the oxide of lime. It is white, and crystallizes in plates. The process consists in macerating the bark in a sufficient quantity of cold water, in concentrating the liquid, and setting it aside to spontaneous evaporation. The salts gradually separate, and are purified by repeated crystallizations. The quantity procured amounts to about seven parts for every hundred of bark employed.

2. Yellow.

*Pale Peruvian bark.*—This is the common variety of bark. It has not yet been subjected to a correct chemical analysis. Its taste is astringent and bitter, and is disagreeable. It is supposed to contain bitter principle, tannin, extractive, and resin. Besides these, it contains a principle first pointed out by Seguin, and which Dr Duncan junior published some experiments on. It is distinguished by the property of preventing infusion of galls; but as this property is common to a considerable number of substances, it is insufficient alone to characterize it.

3. Pale.

*Bark of cinchona Caribæa.*—This bark was first

\* *Ann. de Chim.* xlviii. 65.† *Nicholson's Jour.* vii. 226.



Book IV.

made known by Dr Wright, who published a botanical description of the tree, with a figure, in the Philosophical Transactions \*; and an account of the medicinal properties of the bark in the London Medical Journal for 1787 †. A description of a tree to which the same name is given, together with a chemical analysis of the bark, was published in the Journal de Physique for 1790 ‡ by M. Vavasseur; but it is not quite certain that the plants are the same.

4. Vauquelin has lately examined all the different species of cinchona, or Peruvian bark, which he could procure, in order to determine, if possible, how far they differ from each other, and what the constituents are that act as febrifuge §.

Species of bark.

They may be divided into three sets:

I. The infusions of the first set precipitate the infusion of nutgalls, but not that of glue.

II. The infusions of the second set precipitate glue, but not the infusions of nutgalls.

III. The infusions of the third set precipitate stone glue, nutgalls, and tartar emetic.

The following Table exhibits the effects of the different reagents upon all the barks tried. As Vauquelin has not given the botanical name in all cases, it is difficult, notwithstanding his descriptions, to ascertain the real names of the different species tried. Indeed, there is reason to believe that the same species occur in different parts of the Table under different names:

\* Vol. livii. p. 504.

† Vol. xxxvii. p. 241.

‡ Vol. viii. p. 239.

§ Ann. de Chim. lxi. 11.

Barks.	Precipitate by glue.	Precipitate by tannin.	Ditto by tartar emetic.	Chap. II.
Yellow bark.....	White		Copious	
Quinquina of Sta Fé	Reddish	Copious	o	
Grey quinquina.....	White	ditto	White	
Quinquina griseanella	Brown	o	o	
Red quinquina.....	Red	o	Yellowish white	
Grey quinquina.....	White	Yellow	ditto	
Quinquina gris plate..	o		o	
Cinchona pubescens..	o	Yellow	Yellowish white	
Cinchona officinalis..	o	ditto	o	
Cinchona magnifolia	Copious	o	o	
Quinquina pitton vrai	o	Copious	Copious	

*Barks brought from Peru by Humboldt.*

Quinquina of Loxa...	Copious	Copious	Copious
Quin. white of Sta Fé	o	o	o
Quin. yellow of S. Fé	o	Copious	Copious
Quin. red of Sta Fé..	Copious	o	o
Q. yellow of Cuença	o	o	o
Quinquina, ordinary..	Copious	Copious	Copious
Infusion of nutgalls..	Copious		Yellow white
Oak bark.....	ditto		o
Cherry-tree bark.....	o	o	o

All the barks strike a green with iron, and most of them precipitate it of that colour.

The substance in these barks which precipitates tannin has a brown colour and a bitter taste; it is less soluble in water than in alcohol. It precipitates tartar emetic, but not glue. It has some resemblance in its

Book IV. properties to the resins, though it gives out ammonia when distilled.

Croton. 5. *Bark of croton eleutheria*.—This bark constitutes the eleutheria and cascarilla of the shops. It is usually in rolled pieces, and has some resemblance to Peruvian bark. It has an aromatic smell, and an agreeable bitter taste. When burnt it emits an aromatic odour resembling that of musk. For the only chemical analysis of this bark hitherto published, we are indebted to Professor Trommsdorf; 4696 parts of it yielded him the following products\*.

Mucilage and bitter principle	864 parts
Resin .....	688
Volatile oil .....	72
Water .....	48
Woody fibres.....	3024

Total 4696

White willow. 6. *Bark of the white willow (salix alba)*.—The bark of this tree, which is common enough in Scotland, is remarkable for its astringent taste, and has been often used in intermittents by the common people. It has lately been proposed by Bouillon la Grange as an excellent substitute for Peruvian bark; being composed, according to him, of the very same constituents to which that bark owes its medicinal virtues. A very superficial examination, however, may satisfy any one, that the properties of the two are very far from similar.

The decoction of this bark has a dark reddish co-

\* *Ann. de Chim.* xxi.

nd, according to Bouillon la Grange, when re-  
 decoctions are made with the same portion of  
 he last is always deepest coloured. It is precipi-  
 undantly by glue, carbonate of potash, and car-  
 of ammonia. Lime-water throws down a pre-  
 at first blue, and afterwards buff-coloured. Sul-  
 f iron throws down a very dark green precipitate.  
 l separates white flakes. When evaporated to  
 , a reddish brittle substance remains, which has  
 bitter taste, and does not attract moisture from  
 nosphere.

n alcohol is digested over this bark, it acquires  
 ish yellow colour. The tincture is rendered  
 by water. When evaporated, it leaves a bril-  
 ellow substance of a very bitter taste, which  
 a moderate heat, and emits an aromatic o-

e experiments indicate the presence of tannin,  
 rinciple, extractive, and gluten, in this bark.

*Bark of quercus nigra*.—This tree, to which the  
*Quercitron* has been given, grows spontaneously  
 in America. Dr Bancroft discovered, about the  
 184, that the inner bark of this tree contains a  
 quantity of colouring matter; and since that time,  
 been very generally used by the dyers. To pre-  
 for them, the epidermis (which contains a brown  
 og matter) is shaved off, and then the bark is  
 in a mill. It separates partly into stringy fila-  
 and partly into a fine light powder.

*Quercitron.*

*Quercitron* bark readily gives out its colouring mat-



Book IV.

ter to water heated to the temperature of 100°. At that heat water dissolves about  $\frac{1}{4}$ th of the bark employed. The infusion has a yellowish brown colour, and is rendered lighter by acids, and darker by alkalies. Alum occasions a scanty precipitate of a deep yellow colour; muriate of tin a copious bright yellow precipitate; sulphate of iron a dark olive precipitate; and sulphate of copper a precipitate of a yellow colour, inclining to olive\*. From these experiments it is obvious, that the colouring matter of this bark is a species of extractive. The other ingredients have not been examined.

Horse chestnut.

8. *Bark of the æsculus hippocastanum*.—The bark of this tree, which forms so fine an ornament in parks and avenues, has lately been proposed in Paris as a remedy in intermittents, and a set of observations on it have been published by Mr Henry†. Water or moderately strong spirits are the best solvents of it. Strong alcohol dissolves but little. The watery infusion has a fawn colour and a bitter taste, without astringency. It is precipitated abundantly by gelatine, and sparingly by acids. It precipitates iron green. With nitrate of mercury it forms a copious precipitate. The infusion of nutgalls and tartar emetic produce no effect upon it. From these properties it is obvious that it differs entirely in its constituents from the different species of catechu examined by Vauquelin.

Cinnamon.

9. *Cinnamon*.—This is the inner bark of the *lauræ*

\* Berthollet, *Éléments de l'Art de la Teinture*, E. 252.† *Ann. de Chim.* lxxvii. 105.

cinnamon, a tree which grows chiefly in Ceylon, Chap. II.  
it is cultivated for the bark.

Its bark has a reddish brown colour, and consists of rolled pieces which break into splinters. It has a very pleasant aromatic smell, and a pungent but agreeable taste. Its properties are owing entirely to a volatile oil which it contains. This oil may be obtained by infusing the bark in alcohol, and then separating the alcohol from the oil by distillation. It has a yellowish colour, and an extremely pungent taste and smell. The quantity yielded by cinnamon is very small. From 16 ounces of bark, Neumann obtained two scruples and a half of oil. When water is distilled off this bark, it comes over milky, from the accompanying oil, which it retains with great obstinacy; little separating till the mixture has stood a very considerable time\*.

---

## SECT. V.

### OF LEAVES.

The leaves of plants bear a greater resemblance to each other than any of the parts already treated of. They are covered only with an epidermis; the cortical parts of the bark being wanting. Below the epider-

---

\* Neumann's *Chemistry*, p. 402.

**Book IV.**  
**Properties.** mis is a pulpy matter, usually green, which contains resinous matter and a portion of gluten. Below this is the fibrous matter, or rather the vessels which form the outline of the leaf. Alcohol extracts the green colouring matter of leaves, and so do oils but not water. It is remarkable, that even those leaves which are not green still give a green tincture to alcohol. The green colour soon fades when exposed to air, either in solution, or separated by evaporation\*. Many leaves give a yellow colour to cloth, which may be fixed by means of alum. Hence the much greater number of yellow dyes than of any other colour. The leaves of woad (*reseda luteola*) are those which give the finest yellow, and they are much employed by the dyers on that account.

No extensive series of chemical experiments having hitherto been made upon leaves in general, I must satisfy myself with noticing the few specimens which have been examined by chemists. The following are the most remarkable of these.

**Senna.** 1. *Senna*.—This drug, much used in medicine as a mild purgative, is composed of the leaves of *cassia senna*, a small shrub which grows chiefly in Egypt, from which country it is imported into Europe. It has been chemically examined by Bouillon la Grange.

The leaves are lanceolate, of a yellowish green colour, an aromatic and somewhat disagreeable odour, and a bitter taste. Steeped in water, senna communicates to that liquid its peculiar smell and taste, and a reddish brown colour. The strong mineral acids, ox-

---

\* Lewis, Neumann's *Chemistry*, p. 434.

cid, and the alkaline carbonates, throw down a precipitate; so do barytes water, and the nitrates of mercury, silver, and lead. The infusion of galls strikes a greenish buff colour, and throws down a slight precipitate.

Alcohol throws down a precipitate, which, if we believe Bouillon la Grange, is composed of about two parts of carbonate of lime and one part of silica\*. The residual liquor contains extractive, with some salts, the bases are potash and magnesia.

When the infusion is exposed to the air, a substance separates from it. A precipitate is obtained also by uratic acid. This precipitate is of a lemon yellow colour, insoluble in water, has a bitter taste, dissolves in alcohol and alkalies, and, in short, possesses the characters of resin.

The chief matter taken up from senna by water is a green extractive, which is converted into a species of resin by the absorption of oxygen; to this substance the medicinal qualities of senna are owing. If we believe Bouillon la Grange, its activity depends upon its absorbing oxygen.

Hundred parts of water boiled on senna are sufficient to deprive it of all the soluble matter which water is capable of extracting. Alkali separates from the residue a portion of matter similar to the extractive, also by exposure to the air. The leaves are now green, and give out a green matter to alcohol. This sub-

---

do not clearly understand this part of the analysis. The precipitate is stated to be partly soluble in water and alcohol, and yet to be insoluble by alcohol. These characters surely do not apply to carbonate of lime and silica.



## Book IV.

stance is insoluble in water and alkalies, and is whitened by oxymuriatic acid, and rendered less soluble in alcohol. These properties indicate a peculiar substance. 244.6 parts of senna yield to these different menstrua 79.6 parts, or rather more than  $\frac{1}{3}$  of soluble matter. When the watery infusion of senna is evaporated to dryness, and the residue burnt, it yields potash, sulphate of potash, carbonate of lime, magnesia, and silica\*.

## Worm-wood.

2. *Wormwood*.—This is the leaves, and likewise the stalks and flower-tops of the *artemisia absinthium*, a plant which grows wild in many parts of Britain. Wormwood has a strong smell, rather disagreeable, and an intensely bitter taste. Its smell is owing to a volatile oil which it contains. It contains, besides, a considerable portion of bitter principle. No late analysis of wormwood has been made. The last is that of Kussmuller†, who obtained, by water, from 12 parts of wormwood, the following products :

Resin . . . . .	0.48
Muriate of potash . . .	0.12
Vegetable acid . . . .	0.50
Ditto combined with potash	2.14
	<hr/>
	3.24

The residue, after the action of water, being burnt, left an ash, which, from 12 ounces of wormwood, contained the following substances :

---

\* *Ann. de Chim.* xxvi. 3.

† *Ibid.* vi. 33-

Muriate of potash	. 3 grains
Sulphate of potash	. 1
Carbonate of lime	. 59
Alumina	. . . . 5
Sulphate of lime	. . 5
Silica	. . . . 4
Oxide of iron	. . . 3

3. *Tobacco*.—This substance is formed from the Tobacco.  
leaves of the *nicotiana tabacum*, a plant which is a native of Virginia, where it is cultivated very extensively for the purposes of commerce. Its name was given it from Tabaco, a province of Mexico, where it was first observed, and whence it was originally brought to Europe\*.

Tobacco, when properly cured, has a yellowish green colour, a strong, and rather unpleasant smell, and a very acrid taste. When burnt it emits a strong odour, which to many is peculiarly grateful. When swallowed, it acts very violently upon the system; and when taken in sufficient quantity, proves fatal. No exact chemical analysis of tobacco has been published; though several of its constituents have been ascertained.

When distilled, it yields an oil of a very acrid and poisonous nature†. To this oil, which has a green colour, the peculiar properties of tobacco are at present ascribed. When long boiled, tobacco loses much of its virulence, owing probably to the dissipation of the oil, and the decoction acts merely as a mild aperient.

\* For a detailed account of the culture and management of tobacco, see Tatham's Essay on its culture and commerce, published in 1830.

† Neumann's *Chem.* p. 356.

**Book IV.** When distilled with water or alcohol, no oil whatever is obtained.

When the juice of tobacco is evaporated to dryness, it leaves a reddish matter, of an acrid taste, which gives no colour to alcohol. Muriate of potash is present in it in considerable quantity\*. Besides these substances, tobacco appears to contain a portion of bitter principle, some extractive, and a quantity of mucilaginous matter.

**Asparagus.** 4: *Asparagus*.—This plant has been lately analysed by Robiquet. I place the result here rather than any where else, because the whole plant was employed, and the leaves constitute the principal part of it.

M. Robiquet reduced the asparagus to the state of a pulp, and separated its juice by expression. A feculous matter was separated from this juice by filtration. Boiling alcohol dissolved a portion of this fecula, and left matter which possessed the properties of gluten. As the alcohol cooled, a portion of wax precipitated. The alcohol, by evaporation, left a green acrid matter, intermediate in its properties between resin and volatile oil.

The filtered juice had the appearance of whey, and reddened the infusion of litmus. When heated it deposited flakes, which were considered by Robiquet as albumen. When left for a long time to evaporate in the open air, a quantity of asparagin and of saccharine matter, having the appearance of manna, separated in crystals. The juice was inspissated, and treated with alcohol. A portion dissolved; the residue was dissolved in water.

The alcoholic solution, when treated with sulphur

---

\* Boullon La Grange, *Jour. de Phys.* LXXIX. 1793.

acid, and distilled, yielded vinegar. When this solution was evaporated to dryness and burnt, the ashes consisted of potash, carbonate of lime, and phosphate of potash and of lime. Hence it was probable that the acetic acid was combined with potash and lime.

The watery solution reddened vegetable blues. The infusion of nutgalls throws down a precipitate from this solution. The residue contains a peculiar extractive matter and a colouring matter; and doubtless, also, asparagin and sugar.

Such is the result of Robiquet's very ingenious and interesting analysis of this substance \*.

5. *Aloes*.—This is the inspissated juice of the leaves of a variety of the *aloe perfoliata*, a plant which grows in Socotora, an island in the East Indies. Aloes has a resinous appearance, a reddish yellow colour, a bitter taste, and an aromatic smell. It has been recently examined by Braconnot, who found it composed chiefly of a peculiar matter similar to that detected by Vauquelin in many febrifuge barks, and to which Braconnot proposes to give the name of *resinous, bitter principle* †. Trommsdorf, on the other hand, and Bouillon La Grange and Vogel, consider it as composed of resin and a peculiar extractive matter ‡. Fabroni has discovered, that the recent juice of the leaves of the aloe has the property of absorbing oxygen, and of assuming a fine reddish purple, and of yielding a pigment which he strongly recommends to the painter §.

6. *Atropa belladonna*, *deadly nightshade*. The leaves of this plant have been lately examined by Melandri:

\* *Ann. de Chim.* lv. 132.

† *Ibid.* lxxiii. 18.

‡ *Ibid.* p. 11. and 155.

§ *Ibid.* xxv. 301.



Yucca. — The leaves of this plant, when treated with crocus, yield a green extractive, a muriate of potash, a soft green extractive, and a substance which Chevreul considered as animal extractive, no doubt analogous to the extractive of the same name.

*Rhubarb*. — The leaves of this plant have been lately examined by Bouillon La Grange, and were found to contain a considerable quantity of potash and of malic acid †.

*Indigo*. — The leaves of this plant have been subjected to analysis by Chevreul. The leaves were first separated by filtration from the green juice, with which it was mixed, deposited on a filter, and yielded a blue powder, which possessed the properties of indigo. When heated, white flocks separated, which Chevreul considered as gluten. When distilled, the liquid that came over yielded traces of a volatile oil, of ammonia, and of sulphur. When distilled with sulphuric acid, the liquid that came over contained acetic acid and prussic acid. Evaporated to dryness, and digested in alcohol, it yielded to that liquid a quantity of matter described in the last Chapter of this Work, under the name entitled *Of Indigo* by the name of green matter. It yielded also a yellow coloured extractive, and the following salts; nitrate of potash, muriate of ammonia, acetate of potash, muriate of potash, and pure acetic acid. The residue thus deprived of the substances soluble in alcohol consisted of gum, yellow extractive, supermalate of lime, sulphate of lime, and a salt which Chevreul considered as citrate of lime-and-magnesia.

the green fecula being examined, was found to consist of green coloured resin, wax, indigo, gluten, and woody fibre. The dry matter of the leaves, from which the juice had been expressed, yielded woody fibre, green resin, wax, indigo, nitre, a red coloured matter, malate of zinc, and traces of some other salts \*.

9. The leaves of the *indigofera anil*, examined by the same chemist, yielded the same products with the isatis, but the quantity of indigo obtained was much greater †.

10. Besides the leaves enumerated in this Section, many others are employed in medicine, especially on the continent, where the Materia Medica includes a much greater variety of articles than in Britain.

---



---

## SECT. VI.

### OF FLOWERS.

The flowers of vegetables, on account of the great variety and beauty of their colour, attracted at an early period the attention of dyers and painters; but, upon examination, few have been found capable of yielding serviceable materials for either of these artists. The blue flowers, in general, readily give out their colour to water; though there are some from which

Blue flowers.

---

*Mém. de Chim.* lxxviii. 284.  
xxv. 301.

† *Ibid.* p. 305.

Book IV.

water gains only a reddish or purplish hue. Scarcely any give a blue colour to alcohol: some give a red colour to that liquid, and some no colour whatever\*. The expressed juice of most of these flowers is blue. This colour is changed into red by all acids, and into green by all alkalies and alkaline earths.

The nature of the colouring matter of these flowers is still unknown. But whatever it be, it is of a very perishable nature; for the flowers cannot be dried without losing their colour almost entirely. The more rapidly they are dried, and the more completely the air is excluded, the more of their colour they retain; but even after that, they mostly lose it altogether, and become white or yellow. The expressed juice gradually becomes purple, and soon fades altogether. Even when reddened by acids, these juices soon become purple, and at last colourless. The green colour induced by alkalies gradually changes to a yellow, which has some permanence†.

**Red.** The colour of the red flowers, in general, is scarcely more permanent than the blue. They all give out a red colour to water. The pale red and purple flowers scarcely tinge alcohol; resembling in this respect the blue flowers, to which indeed, in point of colouring matter, they seem to approach very nearly. The flowers, which have a full red colour, give a deep red tincture to alcohol; the pale red are tinged green by alkalies, and their red heightened by acids, like the blue flowers; but this is not the case with the full red flowers‡.

---

\* Lewis, Neumann's *Chem.* p. 430.

† Lewis, *Ibid.* p. 431.

‡ Lewis, *Ibid.*

The colour of the yellow flowers, whether pale or deep, is much more durable. They, in general, dry very well, and give out their colouring matter both to water and alcohol. When wool or silk is previously impregnated with alum and tartar, it receives a durable yellow colour when boiled with yellow flowers. Some of them, indeed, appear to be used by dyers for this purpose. Neither acids nor alkalies destroy the yellow colour of flowers, though both alter its shade; the acids rendering it paler, and the alkalies deeper. Alum likewise heightens the colour, though not so much as alkalies\*.

Even white flowers are by no means destitute of colouring matter. Many of them strike a green with alkalies, though acids do not turn them red. Some of them seem to contain the same colouring matter as yellow flowers. Thus the petals of the *convolvulus sepium*, though white, give a deep yellow or orange colour to water, which is rendered paler by acids, and heightened by alkalies and alum. The vapours of sulphurous acid do not alter white flowers, though they destroy the colour of all others†.

For these curious observations on the colours of flowers, we are indebted to Dr Lewis. Most of them contain a peculiar volatile oil, to which they owe their smell. Their other constituents remain still unknown, as few of them have been subjected to chemical analysis. The following are the species which have hitherto attracted the attention of chemists or artists:

1. *Flowers of the carthamus tinctorius*.—This is

*Carthamus tinctorius*.

\* Lewis, Neumann's *Cém.* p. 431.

† Ibid. p. 432.



**Book IV.** an annual plant, cultivated chiefly in Egypt for the sake of the flowers. The petals are originally of a fine red, but lose much of their colour on drying. It is from this substance that the *rouge*, or red pigment, employed by the ladies, is extracted. When the flowers have come to maturity, they are pulled, their juice expressed, the residue washed repeatedly with salt water, and exposed upon mats to dry. Care is taken to cover them from the action of the sun during the day, and to expose them to the action of the evening dews, in order to prevent them from drying too fast. In this state they are brought to Europe under the name of *safflower*, and the colouring matter is extracted from them by different artists. The process has been kept secret.

Beckmann published a very elaborate set of experiments on the flowers of the carthamus, in 1774\*. Little addition was made to our knowledge of this substance after that period, till 1804, when Dufour published an excellent analysis of it†; and his observations have been since confirmed by those of Marchais‡.

**Analysis.**

The flowers of the carthamus contain two colouring matters: a yellow, which is soluble in water, and has hitherto been applied to no use; and a red, which is employed by the dyers, &c. and which constitutes the pigment called *rouge*. The yellow colouring matter dissolves readily in water; but it is very difficult by that means to separate the whole of it. The method followed by Dufour was to put the carthamus in a linen cloth, and knead it continually between the fingers, while a streamlet of water dropt upon it. By

\* In the *Göttingen Transactions* for that year.

† *Ann. de Chim.* xlviii. 283.

‡ *Ibid.* l. 73.

During this process, and then steeping it in water, assumed a fine red colour. The liquid which passed, being filtered to separate some portion of the carthamus, and some impurities with which it was mixed, had a yellow colour. When heated to about  $145^{\circ}$ , a mass of flakes formed in it, consisting of albumen, and of gluten. These were separated by filtration, and the liquid evaporated to dryness. The extract obtained had a yellow colour and a strong taste. Water dissolved the whole of this extract, except a portion of brown matter, which possesses the properties of resin. The watery solution gives a red colour to soluble blues, and is precipitated abundantly by infusion of galls, but not by glue. Oxymuriatic acid destroys the yellow colour, and renders it white. When evaporated to dryness, and treated with alcohol, a portion dissolves, and a portion remains undissolved. The soluble portion is chiefly extractive; the insoluble yellow colouring matter.

When the residual carthamus is digested for a sufficient time in alcohol, that liquid assumes a brick red colour. When this alcoholic solution is sufficiently concentrated by evaporation, a matter separates in it, which has the appearance of honey, and possesses properties analogous to those of wax. Scarcely any colouring matter could be procured from the alcoholic solution.

Desfleur, after various unsuccessful attempts to obtain the red colouring matter of carthamus in a separate state, at last succeeded by the following process, founded on the strong attraction between the red matter and cotton. Having deprived the carthamus as much as possible of its yellow colouring matter, by means of

Book IV.

water, he macerated it for an hour in a weak solution of carbonate of soda. He then decanted off this solution, put into it a quantity of cotton, and then dropt into it lemon juice, till the liquid acquired a fine cherry red colour. After standing 24 hours, the liquid lost its red colour, the whole colouring matter having united with the cotton and dyed it red. The cotton was taken out, and washed repeatedly in water, to separate any of the yellow colouring matter which might have adhered. It was then put into a very diluted solution of carbonate of soda. This alkali separated the colouring matter from the cotton, dissolved it, and assumed a yellow colour. The cotton being removed and lemon juice dropt into the solution, a fine rose-colour powder gradually separated, and at last precipitated. This was the red colouring matter.

From this process, we see that the red colouring matter has a stronger attraction for cotton than the yellow and that by means of cotton the two pigments may be separated. We see, too, that it is soluble in alkaline carbonates, but precipitated by acids. The alkalies dissolve it also but alter its nature. The solution of it in the alkaline carbonates is yellow. It is insoluble in water. Alcohol dissolves it readily, and assumes a fine rose red colour. When this tincture is heated, it assumes a shade of orange. It dissolves likewise in ether, but not well. The oils, both fixed and volatile, have no action on it. When distilled it yields very little water, scarcely any gases, a little oil, and a portion of charcoal equal to  $\frac{1}{3}$  of its original weight. When this charcoal is burnt, no sensible portion of ash remains behind. From these properties, for which, as well as for almost all the other facts respecting carthi

Book IV.

a precipitate with glue, and does not alter the solution of tartar emetic. With sulphate of iron it strikes a deep green, which passes into black on drying. The mineral acids occasion brown precipitates, but the alkaline carbonates produce no change in it\*.

When the flowers are macerated in alcohol, the liquid acquires a yellow colour. It reddens vegetable blues, strikes a green with sulphate of iron, and becomes milky when mixed with water. When this tincture is distilled, the alcohol which comes over has a bitter taste, but does not alter vegetable blues; while the liquid which remains in the retort is very acid, precipitates with water, and strikes a green with sulphate of iron. When evaporated to dryness, a bitter acid powder remains, seemingly of a peculiar nature †.

When distilled, the flowers of the arnica yield a yellowish acid liquor, which strikes a black with sulphate of iron. This liquid is covered by a quantity of oil. When these flowers are burnt, the residual ashes contain potash, carbonate of potash, muriate and sulphate of potash, and carbonate of potash ‡.

Saffron.

3. *Saffron*.—This yellow pigment is composed of the pistils of the *crocus sativus*. The flowers of this plant are of a purplish blue colour, but the upper part of the pistil is of a deep orange, and divided into three fleshy filaments. These are carefully picked out, dried, and pressed into cakes.

Saffron is in long broad filaments of a deep red colour without any yellow; moderately dry, yet flexible

---

\* Bouillon la Grange, *Ann. de Chim.* lv. 38.

† Ibid. lv. 39.

‡ Ibid.



and soft, and difficultly reduced to powder. It has a strong agreeable smell, affecting the eyes, and drawing tears from them, and a pungent, and somewhat bitter taste \*.

Chap. II.

Hitherto saffron has not been subjected to a correct chemical analysis. From the experiments of Neumann, it does not appear that any volatile oil can be procured from it by distillation. It is probable, however, that it owes its strong smell to such a principle, though in too small a quantity to be easily obtained separate. The colouring matter of saffron is equally soluble in alcohol and water; and, if we believe Hermbstadt, is pure extractive.

---

## SECT. VII.

### OF POLLEN.

THE antheræ of most vegetables, at the time that the flower is in perfection, is covered with a considerable quantity of a powdery matter, usually of a yellow colour, which, falling upon the pistil, is supposed to impregnate it. This matter is known by the name of *pollen*. In some plants, especially those in which the male and female flowers are separate, the quantity of it is so great, that it may easily be collected.

---

\* Neumann, p. 401.

Book IV.  
Experiments of  
Lewis.

The first person who examined this powder was Dr Lewis ; but in his time chemistry had not made sufficient progress to enable him to make a complete analysis. He found that alcohol, in which it is macerated, acquires a bright yellow colour, and that water takes a duller yellow, while the undissolved portion is of yellowish white colour. The colour of these infusions is heightened by alkalies, and turned red by acids. When alkalies are dropt into the reddened solution, a deep yellow colour is restored \*.

Fourcroy and Vauquelin have lately published a detailed analysis of the pollen of the *phoenix dactylifera*, or date tree, which may be considered as furnishing a pretty correct view of the properties of this class of vegetable substances. At least it is probable, that the pollen of different vegetables does not differ nearly so much from each other as the other parts of plants.

Pollen of  
the date  
tree.

The pollen of this tree is so abundant, that at the season of fructification, it surrounds the plants like thick dust. The specimen examined was brought from Egypt by Delille. Its colour was sulphur yellow, its taste was sourish and unpleasant, it reddened the infusion of litmus, and communicated to water a yellow colour, and a sensible degree of acidity. The watery infusion was precipitated by lime water and ammonia, by alcohol, and by some metallic salts.

Action of  
water and

When pollen was washed in cold water, that liquid acquired a reddish brown colour, a sourish taste and smell, not unlike that of beer. When evaporated, the liquid left a reddish brown matter, which had the con-

tence and odour of melasses; its taste was acid, but disagreeable. Cold alcohol produced no effect upon this matter, but by the assistance of heat it dissolved a portion of it, and assumed a dark colour. The residue had more consistence, and was less coloured. It dissolved with facility in water, allowing at the same time greyish bulky matter to separate. Thus the matter taken up by the watery infusion from pollen has been divided into three portions.

Chap. II.  
Alcohol.

The alcoholic solution being concentrated by evaporation to the consistence of an extract, had a red colour, the odour of baked apples, and a taste strongly acid, but disagreeable. It presented all the characters of malic acid. The grey matter, which refused to dissolve in water, possessed the properties of phosphate of lime.

The aqueous solution was ascertained to consist chiefly of phosphate of magnesia, malic acid, and an animal matter, which formed a copious precipitate with the infusion of nutgalls.

The pollen, thus deprived of its soluble matter, being exposed on filtering paper to the open air for a week, instead of drying assumed the form of a paste, and ran rapidly to putrefaction, emitting an odour similar to that of old cheese. When dried, this matter became semitransparent, and of a consistence resembling that of glur. Before being dried it mixed readily with water, and exhibited the characters of soap. The fixed alkalies showed the presence of ammonia in it. When distilled there came over a watery liquid, which gradually became coloured as the distillation advanced: some time after there came over a red coloured oil and carbonate of ammonia, partly in crystals,

Insoluble  
parts

Book IV.

and partly in solution. The liquid also contained a portion of the oil in the state of a soap. The charcoal left was voluminous, and difficult of incineration. When burnt it left a considerable portion of phosphate of lime.

Action of acids.

The pollen is partly soluble in muriatic acid. The nitric acid reduces it to a paste, azotic gas is disengaged and afterwards, on the application of heat, nitrous gas and carbonic acid. A yellowish oil separated and swam upon the surface, and alkalies separated earthy phosphates and oxalates. When the liquid was evaporated to dryness, it left a yellowish red matter, extremely bitter, tenacious, and adhesive, and perfectly soluble in water. This matter, from the description of it, must have been a species of artificial tannin. Thus it appears, that by the action of nitric acid, the portion of the pollen which is insoluble in water is converted into oil and artificial tannin. The oily matter became solid on cooling, and possessed almost exactly the properties of tallow treated with nitric acid.

Strong alkaline leys dissolve the pollen, and assume with it the properties of soap, while ammonia is disengaged.

When the pollen, mixed with water, is set aside to ferment, it disengages the odour of new cheese, and assumes the form of a tenacious mass. Its taste is extremely sharp; it contains abundance of ammonia, partly united to oil, and partly to malic acid. From all these phenomena, there is reason to believe that the insoluble part of the pollen approaches vegetable gluten in its properties; or rather, that it is intermediate between gluten and albumen.

Such are the properties and constituents of the pollen



of the date tree, as far as they have been ascertained by Fourcroy and Vauquelin \*. We may conclude from them, that it approaches very much to the nature of animal matter. Chap. II.

Professor Link has lately examined the pollen of the hazle nut. It differs a good deal from that of the date tree just described. He found in it tannin in great abundance, a resin, a good deal of gluten, and a little fibrin †.

---

## SECT. VIII.

### OF SEEDS.

THE seeds of vegetables, constituting one of the most important articles of food, and being the materials from which a variety of useful substances are procured, have been more subjected to chemical experiments than any of the other parts of plants.

They all contain a considerable portion of starch, though this matter differs somewhat in its properties in different seeds. Gluten is likewise a common ingredient, but extremely various both in its quantity and in its appearance. Some seeds contain a saccharine matter, as those of the *Lycopodium*; but the quantity is always small, and its properties are hardly ever the same as Constitu-  
ents.

---

\* *Mém. de Mus. d'Hist. Nat.* i. 417.

† *Ann. de Chim.* lxiij. 292.



Book IV.

those of true sugar. Fixed oil is also a common ingredient. In the seeds of the grasses, the proportion of it, if any can be detected, is always small: the same remark applies to the seeds of the papilionaceous plants; but the seeds of the cruciform plants abound in a limpid and nearly insipid oil. In some seeds a volatile oil is present, but this is not common. Some possess a peculiar colouring matter; some possess a portion of bitter principle, as the seeds of the common broom and of the coffee plant.

Saussure junior has lately shown that wheat, and probably every other kind of corn, yields a quantity of phosphorus, if it be charred in a moderate heat, and the charcoal be afterwards violently heated in a porcelain retort. He has shown that the phosphorus, in this case, is owing to the decomposition of phosphate of potash, which exists in these seeds, and which is decomposed by the charcoal at a very high temperature. He has shown that phosphate of soda, and even phosphate of lime, may be decomposed in the same way\*. Thus the observations of Margraf, and some of the earlier chemists, respecting the phosphorus which may be obtained from the seeds of plants, have been verified.

I shall in this Section enumerate, in the first place, the properties of those seeds which are known by the name of *corn*, and are used as articles of food; then the seeds of the papilionaceous plants; namely, peas, beans, vetches, &c. which are likewise employed as food. The seeds of the remaining tribes of plants have been hitherto but imperfectly examined; we can only there-

---

\* *Ann. de Chim.* lxx. 189.

fore detail the experiments hitherto made, without any attempt at arrangement. Chap. II.

The most important genera of corn are, wheat, rye, oats, barley, rice.

1. Wheat, the *triticum hybernium* (and other species) Wheat. of botanists, has been cultivated from time immemorial in Europe and the northern parts of Africa, and the seeds of it employed as one of the most important articles of food. Indeed wheat flour is the only substance known from which good loaf bread can be made. The seeds, when ripe, are ground to a fine powder, and by passing this powder through cloth sieves, of various degrees of fineness, it is separated into distinct portions. The fine flour constitutes the greatest portion; and the *bran*, which consists of the outer coat of the seed, and which is the coarsest of all, constitutes the next greatest portion.

Hitherto the flour of wheat only has been subjected to a chemical examination; while the bran, which may vary from one-third to one-fourth, has been neglected. The two most remarkable substances in wheat flour are the *starch*, which constitutes by far the greatest part of it, and the *gluten*, which is the next ingredient in point of quantity. It appears also, from my trials, to contain a small portion of *bitter principle*. Saccharine matter exists in it also, though in a very small proportion. Mucilage is mentioned as a constituent by Fourcroy and Vauquelin; and from their experiments, also, it appears that phosphate of lime is present, but that they did not detect any phosphate of potash.\* Constituents.

\* Ann. de Mus. d'Hist. Nat. No. xxxvii. p. 3.

Book IV.

Water in which wheat flour has been macerated for six hours, has an opal colour, and becomes transparent very slowly. Its taste is sweetish, it has the odour of unripe grain, and does not alter vegetable blues. The infusion of nutgalls, oxymuriatic acid, and other acids, occasion a precipitate in it. It becomes very rapidly sour. When heated, yellowish flakes are separated. When concentrated by evaporation, its taste becomes more perceptibly sweet. When inspissated sufficiently, it assumes a golden yellow colour; has a sweet taste, but is, at the same time, acid and acrid; yellowish flakes separate, and a crust of phosphate of lime coats the capsule in which the evaporation is performed. Alcohol coagulates it, and throws down a substance which possesses the properties of gluten. Hence it is evident, that the water owes its properties to the gluten which it holds in solution\*, and probably also to a little bitter principle. It contained also some sugar and mucilage, and phosphate of lime.

Rye.

2. Rye is the seed of the *secale cereale*, a plant cultivated in the northern parts of Europe, in considerable quantity, as an article of food. Bread made of it is much denser than wheaten bread, and has a brownish colour, and a peculiar sweetish taste, which to most persons is rather agreeable. We are indebted to Eimhof for an elaborate analysis of rye-meal. He published the result of his experiments in the summer of 1805†.

Soluble  
part;

A determinate portion of rye-meal was formed into a paste, washed in pure water till that liquid ceased to

\* Fourcroy and Vauquelin, Ibid.

† Gehlen's Jour. v. 135.

acquire any colour, or to take up any thing. The liquid, after filtration, had a yellowish colour, an insipid taste, and a smell like that of new whey. It slightly reddened litmus paper, and was rendered muddy by carbonate of potash, sulphate of silver, and infusion of galls. When raised to the boiling temperature, it became muddy, and a number of white flakes separated. These, when collected andedulcorated, had the appearance of curd. They dissolved in alkaline leys, were insoluble in alcohol, and possessed the properties of *vegetable albumen*. When the liquid was concentrated by evaporation, it deposited a small additional portion of albumen. This being separated, the liquid was evaporated to the consistence of honey, and digested in alcohol repeatedly till nothing more was taken up. The residue was greyish white and insipid: water dissolved it slowly, and the solution, being evaporated, deposited more flakes of albumen. The residue had the appearance of a solution of gum arabic, and when evaporated to dryness, left behind it a portion of gummy matter.

The alcoholic solution became muddy when mixed with water. The alcohol being drawn off by distillation, there remained in the retort an aqueous solution, of a wine yellow colour, with large brownish flakes swimming in it. These flakes, when collected, were found to possess the properties of gluten. They formed a glutinous mass with cold water, the bulk of which contracted when the water was made to boil. Boiling alcohol dissolved it; but ether took up only the colouring matter. Alkalies dissolved it, and acids threw it down again from its solution.



Book IV.

The watery solution, thus freed from the gluten, being evaporated, left an extract of a wine yellow colour. By repeated digestions in alcohol, dilutions with water, and evaporations, it was freed from a portion of gluten, which still adhered to it. Its taste was then sweet, but harsh; its colour wine yellow; and it was soluble in water, alcohol, and ether. It was considered as the saccharine matter of rye.

Insoluble.

The rye-meal, thus freed from the matters soluble in water, was mixed with a great quantity of water, and by repeatedly agitating the liquid, and decanting it off after standing some time, it was separated into two portions; namely, a greyish coloured substance, which, being lightest, did not so soon subside, and a white powder, which possessed the properties of starch. The grey coloured substance, by repeated digestions in alcohol and water, was separated into three portions; namely, gluten, starch, and the coats of the rye-seeds. Such are the constituents of rye-meal, according to Einhoff. The following are the proportions of these different substances, detected by this chemist, in the best rye-seeds and rye-meal. 3840 parts of good rye-seeds were composed of

Constitu-  
ents.

930 husk

390 moisture

2520 pure meal

3840

The same quantity of good rye-meal contained



126	albumen
304	gluten, not dried
426	mucilage
2345	starch
126	saccharine matter
245	hask
208	loss

3840

But the proportion of these substances must vary extremely according to the soil, the climate, and the age of the rye. The gluten of rye differs in several particulars from that of wheat. It is less tenacious and more soluble. When it was allowed to ferment, Einhof perceived a strong smell of nitric acid, which is peculiar to this species of gluten. The starch of rye bears a striking resemblance to that of wheat. Like this last, it does not form a colourless solution with boiling water, and always precipitates at last, when the solution is left a sufficient time at rest.

Einhof did not examine the ashes of rye; but from the experiments of Schræder, we know that the same quantity, analysed by Einhof, namely 3840, yielded the following fixed substances\*:

Ashes.

3.90	silica
3.35	carbonate of lime
3.55	carbonate of magnesia
0.35	alumina
0.80	oxide of manganese
0.22	oxide of iron

12.17

\* Gehlen's Jour. iii. 515.

Book IV.  
Oats.

3. Oats are the seeds of the *avena sativa*, a plant cultivated in considerable quantities as an article of food. No correct chemical analysis of this seed has yet been made. The husk is uncommonly thick, and constitutes a considerable portion of the corn. The proportion of starch is likewise considerable, though it is difficult to free it from another substance with which it is united.

Barley.

4. Barley is the seed of the *hordeum vulgare*, a plant too well known to require any description. Great crops of it are reared annually, partly as an article of food, and partly as a material from which malt liquors and ardent spirits are drawn. This species of corn has been examined of late with considerable attention by chemists, partly in order to form correct conceptions, if possible, of the nature of the process of fermentation, and partly to ascertain the constituents of barley. Fourcroy and Vauquelin published several ingenious remarks and experiments on it in 1806\*, and Einhof published a still more elaborate analysis about the commencement of the same year; having examined this grain in different stages of its growth, and after it was fully ripe†.

Unripe barley.

When unripe barley-corns are triturated with water, the liquid acquires a milky colour. If this process be continued, adding fresh portions of water as long as the liquid passes off muddy, there remains only a green husky matter. When this matter is macerated a sufficient time in cold water, it acquires a greenish grey colour, and when dry has the appearance of vegetable

\* *Ann. de Mus. d'Hist. Nat.* No. XLVII. p. 5.

† *Gehlen's Jour.* vi. 61.

pre. The water in which it was macerated, when boiled, deposits a few flakes of albumen, and when evaporated to dryness leaves a small portion of extractive.

The water with which the barley was at first triturated is at first milky, and gradually deposits a white powder; yet it does not become transparent, though allowed to stand a considerable time. When filtered, it passes through transparent, while a slimy substance of a greenish grey colour remains upon the filter. This substance possesses the properties of gluten. When the solution, now transparent and of a yellowish colour, is boiled, it deposits flakes of albumen. It reddens litmus paper, and is strongly precipitated by lime-water, nitrate of lead, and sulphate of iron, indicating the presence of phosphoric salts.

The liquid being evaporated to the consistence of a syrup, and the residue treated with alcohol, the solution diluted with water, and the alcohol distilled off, to separate some gluten which still remained, a syrupy matter was obtained, having a sweet taste, which was considered as a saccharine matter of the barley. A portion refused to dissolve in alcohol. This portion was considered as extractive.

The white powder which precipitated from the water in which the barley had been originally triturated, possessed the properties of starch.

Such are the constituents of unripe barley, according to the experiments of Einhof. The following are the proportions of each which he obtained from 2880 parts of unripe barley\*.

---

\* Gehlen, vi. 83.

Book IV.  
Constitu-  
ents.

Green husk, &c. ....	478.
Albumen, with phosphate of lime ..	29
Gluten .....	52
Saccharine matter.....	160
Extractive.....	76
Starch .....	420
Volatile matter.....	1500
Loss .....	182

---

2880

Ripe bar-  
ley.

When ripe barley is steeped in water a sufficient time, and then cautiously kneaded between the fingers in a cloth, every part of the grain is washed away except the husk, which by this process may be dried and weighed.

When barley meal, previously made into a paste, is treated in the same way, a brownish residuum remains, consisting chiefly of the husk, though it contains also portions of starch and gluten which cannot well be separated. The water in which the meal has been washed gradually deposits a white powder, but does not become transparent though left at rest. It runs very soon into acidity. Indeed, if we believe Fourcroy and Vauquelin, barley often contains an acid; the water in which it has been macerated reddening the infusion of litmus: this acid is the acetic. The colour of this water is reddish brown. It holds in solution a considerable portion of matter, which, according to Fourcroy and Vauquelin, consists chiefly of gluten, but which Einhof found to be of a more complicated nature, consisting of albumen, or rather gluten, mucilage, and saccharine matter. It contains in solution likewise a notable portion of phosphate of lime.



When barley meal is macerated a sufficient time in alcohol, that liquid acquires a yellow colour, and becomes muddy and more odorous, and by evaporation it is an oily matter of a yellow colour and an acrid taste, having the consistence of butter. This oil burns as a fat oil, and forms soap with alkalies. It is but perfectly soluble in alcohol &c. This oil escaped the observation of Einhof. I obtained it by a process similar to that afterwards described by Fourcroy and Vauquelin; but its colour was asparagus green, and it did not burn with the same readiness as an oil. It has very much the appearance of olive oil coagulated, but its consistence is less, and its colour is darker. To this the peculiar flavour of spirits from raw grain is ascribed at present. If this opinion be well founded, the oil must be dissipated or destroyed by the process of distilling.

The following are the proportions of the constituents obtained by Einhof from 3840 parts of barley-corns:

Constituents.

Volatile matter..... 430

Husk..... 720

Meal..... 2690

Total 3840

From the same quantity of barley meal he obtained

Fourcroy and Vauquelin, *Ann. de Mus. d'Hist. Nat.* No. 100vii. p. 2.



## Book IV.

Volatile matter . . . . .	36
Albumen . . . . .	1
Saccharine matter . . . . .	20
Mucilage . . . . .	1
Phosphate of lime, with some albumen . . . . .	9
Gluten . . . . .	1
Husk, with some gluten and starch . . . . .	250
Starch, not quite free from gluten . . . . .	2530
Loss . . . . .	76

Total 3840

Besides these substances, Fourcroy and Vanquelin ascertained the presence of phosphates of lime and magnesia, and of silica and iron; and I found in it, besides these substances, phosphate of potash and nitrate of soda. The presence of phosphate of potash was ascertained likewise by Saussure junior.

## Rice.

5. Rice, the seeds of the *oryza sativa*, ought to be considered here, on account of the striking resemblance which it bears to barley in its properties; but hitherto this important grain, almost the sole food of a great proportion of the human race, has not been subjected to chemical analysis. We may conclude from analogy, that its constituents are pretty much the same as those of barley.

## Mais.

6. Mais. This is the seed of the *zea mais*, or indian corn. Some experiments on it have been made by Proust. It is converted into charcoal in the usual way, and leaves about  $\frac{1}{4}$ th its weight of charcoal. This charcoal is extremely difficult of incineration. It contains some phosphate of potash\*.

\* Nicholson's Jour. xviii. 239.

ing now given an account of the constituents of various species of corn hitherto subjected to chemi-  
mination, let us proceed to the seeds of the pa-  
aceous plants. The most remarkable of these  
is, beans, kidney beans, lupines, lentiles, &c.

Peas. The seeds of the *pisum sativum* constitute a  
common and nutritive article of food. They have  
ately examined in different states by Einhof\*,  
as devoted his chief attention to this peculiar  
of chemical investigation.

Green  
plant.

treating the green plant nearly in a similar man-  
th barley, he obtained from 3840 parts the fol-  
constituents:

Volatile matter . . . .	3000
Starch . . . . .	53
Vegetable fibre . . . .	400
Gluten † . . . . .	70
Albumen . . . . .	35
Phosphate of lime . . .	4
Saccharine matter . . .	176
Extractive . . . . .	25
Loss . . . . .	77

3840

green pod or husk of the pea, by a similar treat-  
yielded, from 3840 parts ‡,

Pod.

Einhof's Jour. vi. 125.

the same state as that from the leaves of plants, and mixed with  
colouring matter.

‡ Gehlen's Jour. vi. 129.

# PARTS OF PLANTS.

Volatile matter . . . . .	3129
Vegetable fibre . . . . .	344
Starch . . . . .	90
Green gluten . . . . .	22
Albumen . . . . .	17½
Phosphate of lime . . . . .	3½
Saccharine syrup . . . . .	152
Loss . . . . .	61

3840

The peas themselves, when very young, are often filled with a sweet juice, which may be obtained by a slight pressure. Einhof examined this liquid. It has a greenish yellow colour and a very sweet taste. When exposed to the air, thin cuticles formed on its surface, and white flakes precipitated. It gradually underwent a kind of fermentation and became sour. From 1449 parts of this juice, Einhof obtained, by analysis \*,

Albumen . . . . .	10
Extractive . . . . .	18
Saccharine syrup . . . . .	155

This syrup had much the taste of raw sugar, but could not be made to crystallize.

Ripe peas.

From ripe peas, by macerating them in water, and employing a mode of analysis similar to that used for ascertaining the constituents of barley, Einhof obtained the following products. The quantity employed was 3840 parts †.

\* Gehlen's Jour. vi. 120.

† Ibid. p. 12.

Volatile matter . . . . .	540
Starchy fibrous matter, with the coats of the peas . . . . .	840
Starch . . . . .	1265
Animo-vegetable matter . . . . .	559
Albumen . . . . .	66
Saccharine matter . . . . .	81
Mucilage . . . . .	249
Earthy phosphates . . . . .	11
Loss . . . . .	229

---

 3840

The second of these constituents, entitled *starchy fibrous matter*, was what remained after the peas, reduced to a pulp with water in a mortar, had been washed with water till they ceased to discolour it, or to give out any soluble matter to it. This residue was in part composed of the coats of the peas, and partly of a white fibrous matter without taste or smell. When dried, it became yellowish, and was easily reduced to powder; and the powder formed a paste with water, and dissolved like starch in hot water. It then bore a certain resemblance to starch, and agreed in its properties with the fibrous matter of potatoes \*.

Starchy fibrous matter.

The fourth of the preceding constituents, entitled *animo-vegetable matter*, was obtained in this manner: The milky water in which the peas had been macerated, after depositing the starch, still continued muddy, but neither deposited any thing, nor would pass through the filter; but when diluted with its own bulk of water,

Animo-vegetable matter.

---

\* Gehlen's Jour, vi. 123.



of this substance, as far as they have been ascertained by M. Einhof \*. Chap. II.

When 3840 parts of ripe peas were reduced to ashes, the residue weighed 112 parts. From these ashes Einhof extracted phosphoric acid, sulphuric acid, muriatic acid, alumina, silica, carbonate of lime, phosphate of lime, oxide of iron, and phosphate of ammonia and magnesia †.

8. The seeds of the *vicia faba*, a small bean, becoming blackish when ripe, and used as an article of food, have likewise been examined by Einhof. The analysis was conducted in the same way as his other experiments already described. From 3840 parts of the ripe beans he obtained the following substances: Marsh bean.

Volatile matter . . . . .	600
Skins . . . . .	386
Starchy fibrous matter . . . .	610
Starch . . . . .	1312
Vegeto-animal matter . . . .	417
Albumen . . . . .	31
Extractive, soluble in alcohol .	136
Gummy matter . . . . .	177
Earthy phosphate . . . . .	37 $\frac{1}{2}$
Loss . . . . .	133 $\frac{1}{2}$

---

3840 ‡

Fourcroy and Vauquelin, who made experiments upon this substance likewise, found the ashes which it leaves, when incinerated, to consist of the phosphates

---

\* Gehlen's *Jour.* vi. p. 124.

† Ibid. p. 132.

‡ Ibid. p. 136.

Book IV.

Kidney  
beans.

of lime, magnesia, potash, and iron, and of uncombined potash. They could detect no sugar in it\*.

9. Kidney beans, which are the seeds of *Phaseolus vulgaris*, have been likewise analysed by Einhof. They are characterized by the great proportion of animo-vegetable matter which they contain. From 3840 parts of these beans Einhof obtained the following substances:

Skins . . . . .	288
Starchy fibrous matter . . . . .	425
Starch . . . . .	1380
Animo-vegetable matter, not quite free from starch . . . . .	799
Extractive . . . . .	131
Albumen, with some vegeto-animal matter	52
Mucilage . . . . .	744
Loss . . . . .	21

3840 †

Lentiles.

10. Lentiles. To the same indefatigable chemist were indebted for the analysis of the seeds of the *eroum lens*. From 3840 parts he obtained the following substances:

Fibrous matter . . . . .	720
Albumen . . . . .	44
Earthy phosphates, with a little albumen	22
Extractive, soluble in alcohol . . . . .	120
Gummy matter . . . . .	230
Starch . . . . .	1260
Vegeto-animal matter . . . . .	1433
Loss . . . . .	11

3840 †

\* *Ann. de Mus. d'Hist. Nat.* No. xxxvii. 9. † *Gehlen's Jour.* vi. 545.

† *Ibid.* p. 545.

Here the proportion of animo-vegetable matter is still greater than in the kidney bean. Chap. II.

Lentiles were examined by Fourcroy and Vauquelin; but whether the same species as the preceding they do not put it in our power to determine, as they omit the botanical name. The liquid in which the flour of these seeds was macerated was not acid: it had a slight and rather disagreeable taste, and was precipitated copiously by infusion of galls, oxymuriatic acid, and sulphate of iron. In short, it exhibited nearly the same phenomena as are described by Einhof. When the flour of lentiles is digested in alcohol, the liquid assumes a greenish yellow colour, and a bitter acrid taste. When distilled, it has the odour of vanilla very strongly, but acquires a disagreeable smell when mixed with water. The residue is greenish yellow, has the appearance of a thick solution of soap, and a green oil swims upon the surface. The pod of the lentiles contains a portion of tannin\*.

11. White lupine. To Fourcroy and Vauquelin we are indebted for the analysis of the seeds of the *lupinus albus*; the farina of which, according to their experiments, differs from that of all the other leguminous plants hitherto tried, as it contains neither starch nor saccharine matter. They found in it a yellowish green oil of an acrid nature, which approaches the fixed oils in its properties; a vegeto-animal matter, which appears to bear a strong resemblance to gluten; a considerable portion of phosphate of lime and magnesia, and traces of phosphates of potash and of iron†.

White lupine.

\* *Ann. de Mus. d'Hist. Nat.* No. xxvii. p. 10.

† *Ibid.* p. 12.

~~These seeds have been lately~~  
~~examined by Bucholz. The~~  
~~results which he obtained.~~

These seeds yielded by expression  
 three parts of a yellow coloured oil.  
 The residue he procured, by di-  
 stilling in water and coagulation by heat, about  $9\frac{1}{2}$   
 parts of fibrous matter. The mucilage coats and husks of the seeds  
 were obtained by means of alco-  
 hol. The same quantity of a substance to  
 which Bucholz gives the name of *mucilaginous sugar*,  
 and about  $1\frac{1}{2}$  part of *gummy extrac-*

This is the seeds of the *coffea arabica*,  
 a species usually of a small size. It was ori-  
 ginally brought from Arabia, and was unknown in  
 Europe until 1616. The entire fruit has some resem-  
 blance to a cherry. Under a pulpy skin it contains an  
 oval seed, which separates longitudinally into two  
 halves, and covered with a thin coat, and marked longi-  
 tudinally with a furrow on the flat side, where they are  
 joined. The ripe fruit is dried in the sun, and heavy  
 stones pressed over it, by which the seeds are parted  
 and the husks broken. They are afterwards separated  
 by winnowing.

Many experiments have been made by chemists to

\* Gehlen's Jour. vi. 615.

† Neumann's Chemistry, p. 378.



ascertain the constituents and qualities of coffee; Neumann, Geoffroy, Dufour, Kruger, Westfield, &c. published successively the result of their trials on it. The latest analyses are those of Hermann\* and Cadet†. They neither agree well with each other, nor with those of preceding writers. It is probable that these differences ought to be ascribed partly to the different mode of analysis followed, and partly to variations in the berries examined.

The infusion of coffee in boiling water is of a yellowish green colour; but the decoction, by continuing the boiling, becomes brown. It becomes turbid on cooling. The alkalies render it more brown. It strikes a black with sulphate of iron, but does not precipitate with glue. Oxymuriatic acid nearly destroys the colour; but if an alkali be added the liquid becomes red. Cadet obtained a decoction with coffee which produced no effect upon vegetable blues; but other chemists describe it as changing them to red, and Hermann obtained with alcohol a solution which produced the same effect.

Infusion.

When water was distilled from coffee, what came over had an aromatic odour, and a few drops of a substance similar to myrtle wax swam on the surface of it; the residual liquid became milky when mixed with alcohol, and let fall a substance possessing the properties of gum.

When alcohol is digested on coffee, it acquires some colour. The solution when mixed with water becomes

---

\* *Crell's Annals*, 1800, ii. 108.

† *Ann. de Chim.* lviii. 266.

resinous matter. The residue left by the process leaves a substance composed partly of the resinous matter, and partly of the bitter principle. From these experiments, however, we see that coffee contains a little oil, gallic acid, mucic acid, and a principle. It contains also, alumina, lime, muriate of potash, which separates from the residue on burning. The result of Cavendish's analysis is as follows. Sixty-four

Resinous matter	4.75
Bitter principle	1.25
Gallic acid	1.25
Mucic acid	1.25
Oil	1.25
Insoluble matter	1.25
<b>Total</b>	<b>10.00</b>

For the purpose of the following proportions respective-

	Levant.	Martinique.
Resinous matter	74	68
Bitter principle	320	310
Gallic acid	130	144
Mucic acid	1335	1286
Oil	61	12
<b>Total</b>	<b>1920</b>	<b>1926</b>

When coffee is roasted, a portion of tannin is formed in it by the action of the heat. It appears also that a new substance, having a peculiar agreeable smell, is developed; but the nature of this new principle has not yet been ascertained. It is developed also by roasting barley, beans, and a great variety of other vegetables, which are on that account occasionally employed as substitutes for coffee.

Chap. II.  
Roasted  
coffee.

An elaborate analysis of coffee has lately been published by Payssé. He examined with particular care the bitter principle of coffee, first pointed out by Che-nevix, and has endeavoured to show that it is in reality a peculiar acid, to which he has given the name of *caffic acid*. It reddens vegetable blues, but in other respects does not seem better entitled to the name of acid than *tannin*. He detected in coffee, besides this substance, a quantity of albumen, resin, and extractive. It contains a great proportion of matter insoluble in water. Its ashes yield muriate of potash and carbonate of lime. Payssé could not succeed in ascertaining the presence of tannin in roasted coffee. When coffee is distilled it yields, according to him, an acidulous water, a thick brown oil, and carbonate of ammonia. Very little gaseous matter was obtained\*.

14. *Coco*. This is the fruit of the *cocos nucifera*, one of the most valuable vegetable productions of India. A detailed account of the management and products of this tree have been published by Le Goux de Flaix†; but we are still unacquainted both with the

*Coco*.

\* *Ann. de Chim.* lix. 196.

† *Phil. Mag.* xi. 316; and xxi. 77, and 120.

Amigdal. constituents and chemical properties of the nuts. The outer coat is fibrous, and formed by the natives into excellent cordage. The kernel contains a considerable proportion of fixed oil, used by the Indians for lamps\*.

Almonds. 15. Almonds. This is the fruit of the *amygdalus communis*, used both as an article of food and in medicine. There are two kinds, the *bitter* and *sweet*. The latter consists chiefly of fixed oil and starch, or albumen; chemists have not yet ascertained correctly which. Bitter almonds, besides these two substances, probably contain also a portion of bitter principle. Prussic acid is likewise a constituent of them; but hitherto almonds have not been subjected to a regular chemical analysis.

Nutmeg. 16. Nutmeg. This is the seed of the *myristica natchata*, a tree which is cultivated in the Asiatic islands. The covering of the nut is known by the name of *mace*. The nutmeg varies in size and figure; it is furrowed on the outside, and greyish brown internally. Those that want white streaks are the best. From the experiments of Neumann, we learn that this substance contains two species of oil; a volatile oil, to which it owes its peculiar smell and taste, and which in his trials amounted to about  $\frac{1}{4}$  of the nut; and a solid fixed oil resembling wax, and amounting to about  $\frac{1}{2}$  of the nutmeg. He detected also a quantity of gum†; and it is probable, from the appearance of the kernel, that it contains likewise starch. By expression, the solid oil is separated, and mixed with the volatile oil. In that state it is sold under the name of *oil of mace*.

\* See Tennant's *Indian Recreations*, ii. 282.

† Neumann's *Chém.* p. 424.



17. Pepper. This is the seed of the *piper nigrum*, Chap. II.  
 a shrub cultivated in India for the sake of its berries. Pepper.  
 Its outer coat is of a dark brown colour; when deprived  
 of it, the berry is known by the name of *white pepper*.

Pepper, when macerated in cold water, does not lose  
 its shrivelled appearance. The infusion acquires a  
 brown colour, reddens vegetable blues, and has both  
 the taste and odour of pepper. If we repeat the mace-  
 ration a number of times, the liquid still continues to  
 acquire a colour, but it ceases to have the smell and fla-  
 vour of pepper. White pepper does not communicate  
 any colour to water. Hence the colouring matter must  
 reside in the outer coat. It possesses most of the pro-  
 perties of extractive. When pepper is macerated in  
 alcohol, the liquid acquires a light yellowish green co-  
 lour. When distilled, it leaves a green coloured mat-  
 ter, partly resinous, and partly oily. This oil is the  
 source of the odour and taste of pepper. Its taste is  
 extremely hot, and its smell, when dissolved in alcohol,  
 and diluted with water, extremely pleasant. It pos-  
 sesses nearly the properties of volatile oil. When wa-  
 ter is boiled for some time with ground pepper, it ac-  
 quires the property of forming, with the infusion of  
 nutgalls, a precipitate, which dissolves again when the  
 liquid is heated to 120°. Hence it contains a portion  
 of starch. These three substances, starch, oil, and ex-  
 tractive, are the most remarkable of the constituents of  
 pepper\*.

18. Anatto. This pigment is obtained from the seeds Anatto.  
 of the *bixa orellana*, a tree cultivated in Guiana and

---

\* See Nicholson's Jour. ii. 7

Annatto is a berry of the West Indies. When ripe, the capsules are gathered, and the seeds being separated, are pounded, steeped in water for weeks or months, then subjected to the press; and the colouring matter thus obtained is suffered to subside, collected, and dried. A shorter process has been lately proposed by Leblond. The colouring matter, which is confined to the surface of the seeds, is separated by maceration and washing, and then thrown down from the water by an acid\*. The residue is usually in hard cakes, brown without, and white within. It dissolves much more easily in alcohol than in water. Weak alkaline leys dissolve it likewise. The decoction of annatto has a peculiar disagreeable taste. Its colour is brownish red. Alkalies render it orange yellow; and acids throw down an orange-yellow precipitate. The chemical nature of this colouring matter has not been ascertained, though it may be intermediate between extractive and

Species of the *phytolacca decandra*. These berries impart a beautiful purple colour to water, of a very delicate nature. A few drops of lime water change it to yellow, and this yellow liquid is the most delicate colour yet hitherto observed. The smallest quantity of acid restores its purple colour. Braconnot, to whom we are indebted for these observations, has shown, that this colour is ten times as delicate as the infusion of litmus. Ultimately it alters its nature in a few hours,

---

\* *Ann. Chim. Phys.* 1804, t. 13, p. 113.

\* *Ann. Chim. Phys.* 1804, t. 13, p. 113.

and then loses its delicacy as a reactive. It can only be used when recently prepared \*.

Chap. II.

20. The seeds of the *Lycopodium clavatum*, or common club moss, have been long remarkable for their combustibility. They are extremely small; and when blown into the flame of a candle they take fire, with a small explosion, and are used in theatres to imitate the appearance of lightning. They have been lately subjected to chemical analysis by Bucholz. From 1000 parts of the seeds he obtained 60 parts of a fixed oil, soluble in alcohol like castor oil; 30 parts of sugar; 15 of a mucilaginous extract. There remained a matter insoluble in water, alcohol, ether, oil of turpentine, and alkaline leys. But when boiled with the last of these agents, ammonia was disengaged, and a kind of extract formed. When 2000 grains of this substance were distilled, they yielded 290 ounce measures of gas, which was a mixture of carbureted hydrogen and carbonic acid; 1050 grains of a brownish oil, containing ammonia; 330 grains of a watery liquid, holding acetate of ammonia in solution. The residue in the retort, amounting to 310 parts, had very much the appearance of anthracolite. When the insoluble part of the seeds was boiled in nitric acid, a portion of oil soluble in alcohol was likewise formed †.

Club moss.

\* *Ann. de Chim.* lxi. 81.† *Gehlen's Journ.* vi. 593.

THE CACTUS.

SECTION I.

OF THE CACTUS.

The cactus is usually various with  
one or more stems, and has been hitherto subject  
to various names. The most common is an ac-  
cumbent cactus, which is termed, the cactus  
pachyphloeus, and consists of two or more  
flat, fleshy stems, and perhaps the ac-  
cumbent cactus is the most common. They usually  
contain a watery, pulpy matter, sometimes  
containing likewise a fibrous  
substance, and are termed. The colour  
is usually green, and the red, fleshy part  
is sometimes eaten, but very sparingly de-  
scribed as a vegetable, and is not used and well  
known as a vegetable.

The cactus is a considerable re-  
source to the natives, and in a former  
state of the country, the very few vegetable fruits have  
been described, and are to be added to what  
is known. These include, indeed, hitherto p-  
achyphloeus, and grapes.

The cactus is the most common chiefly of  
the cactus, and is the palm of the *samar*  
and is known as such. It is brought to Eng-  
land, and is called to Vauqu-



for an analysis of this substance, published however at a very early period of his chemical career. By treating the pulp of tamarinds, such as they are sold by the apothecaries, first with cold water, and afterwards with hot, he separated the following substances \* :

Supertartrate of potash	300
Gum.....	432
Sugar.....	1152
Jelly.....	576
Citric acid.....	864
Tartaric acid.....	144
Malic acid.....	40
Feculent matter.....	2880
Water.....	9364

---

9752

2. *Grapes*.—Though grapes have been repeatedly examined by chemists, we are not yet in possession of an accurate chemical analysis of their constituents. It has been ascertained, however, that they contain supertartrate of potash, tartaric acid, citric and malic acids†. They contain also abundance of sugar, a portion of mucilage and jelly, some albumen and colouring matter, and, according to Proust, a portion of gluten.

Pears, apples, lemons, oranges, &c. have not yet been subjected to a chemical examination. The few facts which have been ascertained respecting them are detailed in a different part of this Work.

---

\* *Ann. de Chim.* v. 92.

† Bouillon, *Jour. de Phys.* xxix. 3.—Parmentier, *Ann. de Chim.* liii. 219.

LIST X.

1833.

The tubercles connected with the *bulbs*, and ce-  
menting the plant. The *potatoes* is  
the *bulb*.

The tubers in their constituents a  
resembling other parts of plants; but  
the tubers a considerable resemblance  
to the tubers which are cultivated and  
the tubers which constitutes a notable  
difference from the tubers hitherto examined. Hen-  
ce the tubers are articles of food. Fe-  
reus has been subjected to a chemical an-  
alysis, and the following specify the following:

The tubers of the *Linum tuberosum*  
were brought to this country by S.  
The tubers are cultivated in every part  
of the country, constituting one of the most im-  
portant articles of food. The plant and the bulb are  
described.

The tubers are subjected to chemica  
analysis, and published an elaborate dissen-  
sion, and properties, about the  
tubers, and promoted considerably to promo-  
tion on the continent. Dr. Pearse

contributed to the Board of Agriculture a valuable essay on potatoes, containing a set of chemical experiments on them, performed with his usual skill and ingenuity; and very lately Einhof has published a very elaborate analysis of the root in the fourth volume of Gehlen's Journal. Chap. II.

The variety of potatoe which chiefly occupied the attention of Einhof, was that which has a red skin and flesh-coloured juice. When dried by a moderate heat, till they ceased to lose any weight, potatoes were reduced to  $\frac{1}{4}$ th of their original weight\*.

The analysis of this root was conducted by Einhof pretty much in the same manner as his analysis of barley and rye. A determinate quantity of potatoes was reduced with water to a pulp, and then washed on a sieve till the liquid ceased to come off milky, or to hold any thing in solution. What remained on the cloth was the fibrous matter of the potatoe; but it differed essentially from the fibrous matter of most plants. With boiling water it formed a paste similar to that made by means of starch, and when dry it assumed a semitransparent appearance. This matter, when triturated in a mortar, and again washed with water, yielded a considerable portion of starch. The residue, which was of a light grey colour, being triturated a second time, formed a powder which bore a considerable resemblance to starch, both in its appearance and properties.

The liquid with which the potatoe was washed was at first milky, but deposited, on standing, a heavy

---

\* Gehlen's Jour. iv. 457.

Boyle.

white powder, which was *starch*. When filtered it had a carmine-red colour, and reddened vegetable blues. When boiled a flaky precipitate separated, partly white and partly red. This precipitate possessed the properties of albumen. The residue, evaporated to the consistence of an extract, had a brownish colour, was fusible in alcohol and ether, soluble in water, and, according to Einhof, was a mucilaginous matter. The following were the proportions of these various substances obtained from 7000 parts of potatoes :

Chemical  
analysis.

Starch.....	1153
Fusible starchy matter.....	540
Albumen.....	107
Mucilage, in the state of a thick syrup...	312

2112

Chemical  
analysis, 1844  
Schubert.

To determine the nature of the acid which exists in potatoes, Boyle separated the juice of potatoes by a good press. He had first frozen and then thawed them, to facilitate the separation. Lime-water was added in excess to this liquid, and the precipitate was digested in diluted sulphuric acid, to separate the lime from the acid. Thus obtained, it was found to be a mixture of tartaric and phosphoric acids\*. The sap, thus deprived of its acid, contained an excess of lime to some extent, but was mucilag. Einhof found, that this sap became gradually saturated with carbonic acid, even the carbonic acid was kept in close vessels;

\* The phosphoric acid was separated by the method described in the text. The phosphoric acid was found in the potatoes in an undecomposed state, and it was not until the sap was with lime and held in solution, that it became united to the tartaric acid.



and that in process of time, if a sufficient quantity of lime were present, the mucilage acquired a sweet taste; and when treated with alcohol, a portion dissolved, which yielded crystals of sugar. This he considered as a conversion of the mucilage into sugar.

From 1820 parts of dried potatoes, Einhof obtained 96 parts of a greyish white ash. Of these, 64 parts were soluble in water. They consisted chiefly of carbonate of potash; but contained likewise  $10\frac{1}{2}$  parts of phosphoric acid,  $3\frac{1}{2}$  of sulphuric acid, and two of muriatic. The insoluble 35 parts consisted of earths and oxides. From 20 parts of it he obtained

2.5 silica

6.0 lime

4.0 alumina

7.0 magnesia, with some manganese or oxide of iron.

19.5

Einhof examined different kinds of potatoes. He found the same ingredients in all, but the proportions varied considerably. It is not necessary to state the results of his experiments, because the same variations doubtless occur even in the same kind of potatoe.

But as it may be useful to know the quantity of starch furnished by different varieties of potatoe, the following table, drawn up from the experiments of Mr William Skrimshire junior, is subjoined. Five pounds avoirdupois of fresh potatoes were used, and the starch was separated by grating the potatoe, and pouring water upon it placed upon a sarse\*.

\* Nicholson's Jour. xxi. 71.

Book IV.

Substances.	Varieties of potatoes used.											
	Captain hart.	Rough red.	White kidney.	Moulton white.	Yorkshire kidney.	Fluted eye.	Purple red.	Or noble.				
Flour starch	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.	lb. oz. 11. 0. 0.				
Ditto slightly coloured	0 9 3	0 9 3	0 9 3	0 9 3	0 9 3	0 9 3	0 9 3	0 9 3				
Pulp dried	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0	0 0 0				
Water, mucus, and extractive	3 14 3	3 14 3	3 14 3	3 14 3	3 14 3	3 14 3	3 14 3	3 14 3				
Total	5 0 15	5 0 15	5 0 15	5 0 15	5 0 15	5 0 15	5 0 15	5 0 15				

Action of  
frost on po-  
tatoes.

When potatoes are exposed to the action of frost, is well known that they become soft, and acquire sweet taste. This taste is succeeded by a sour taste owing to the rapid evolution of acetic acid, and the root soon passes to putrefaction. From the experiments of Einhof, we learn that the sugar is formed at the expense of the mucilage; for the other ingredients are found, in potatoes sweetened by frost, in the usual proportions. He considers this sweetening process as connected with the vegetative powers of the root.

When potatoes are boiled, they lose from one to Chap. II.  
 $1\frac{1}{2}$  per cent. of their weight. The juice, which may be Boiling.  
 separated from them, is sweet-tasted. The meal is in-  
 soluble even in boiling water, though potatoe starch  
 forms a transparent solution with hot water. Thus it  
 appears, that by boiling, the albumen, fibrous matter,  
 and starch combine together, and form an insoluble  
 compound\*.

From these experiments, it appears that potatoes dif-  
 fer essentially from wheat and barley by containing no  
 gluten. They approach, in some measure, to the na-  
 ture of rye.

2. Garlic.—This is the bulbous part of the root of Garlic  
*allium sativum*, and is well known, and remarkable  
 for its strong smell and peculiar taste. It was much ce-  
 lebrated by the ancients, both as an article of food and  
 as a medicine. It has been repeatedly examined by  
 chemists. The analysis of Neumann, considering the  
 state of the art of examining vegetables at that time,  
 must be considered as very exact†. Cadet has lately  
 subjected it to a chemical examination‡.

When dried, it loses nearly two-thirds of its weight;  
 but this proportion is doubtless subject to considerable  
 variation. The expressed juice of garlic is of a thick  
 consistence like mucilage, and slightly reddens vegeta-  
 ble blues. When diluted with water, and filtered, it  
 yields flakes of albumen when boiled. The residue  
 consists chiefly of mucilage, of which garlic yields a  
 very great proportion, and of extractive. This last is  
 somewhat acrid in its nature. When garlic is distilled

\* Gehlen's Jour. iv. 485.

† Neumann's Chem. p. 485.

‡ Ann. de Chim. liz. 106.

...be employed  
...oxide of  
...our; b

...the 15  
...with  
...which

...liquid  
...then  
...the air  
...units of  
...When  
...For  
...the following

...	33
...	58
...	2
...	156



From 1406 parts of fresh garlic he obtained

Mucilage .....	520
Albumen .....	37
Fibrous matter.....	48
Water, by estimate...	801
	<hr/>
	1406

3. *Onion*. This is the bulbous root of the *allium cepa*. A few experiments on it had been made by Neumann and Cadet. But Fourcroy and Vauquelin have lately published a very curious and accurate analysis of it. When reduced to a pulp, and subjected to the press, it yields a viscid juice, somewhat opaque, at first colourless, but becoming gradually red in consequence of the oil which it contains. It has a strong smell, and reddens vegetable blues. It is precipitated by acetate of lead, lime water, oxalic acid, nitrate of silver, and potash. When distilled it yields a milky liquid, slightly acid, on the surface of which swim some drops of oil. It contains a little sulphur dissolved in the oil; for oxymuriatic acid gives it the property of precipitating nitrate of barytes, and when distilled in a copper vessel some sulphuret of copper is formed. The portion of juice not distilled deposits a fawn coloured sediment, having a strong oniony odour. Alcohol deprives this sediment of oil and of sulphur; the residue seems to possess properties analogous to those of gluten. The liquid, from which this precipitate has separated, contains phosphoric acid, sulphur, and gluten.

When onion juice is kept at a temperature between  $60^{\circ}$  and  $70^{\circ}$  it emits no gas, but it changes its colour successively to red and yellow, and lets fall a fawn coloured sediment. It is now converted into vinegar still

1. The first step in the process is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the situation.

2. Once the problem is identified, the next step is to define the objectives and goals of the project. This helps to clarify what needs to be achieved and provides a clear direction for the team.

3. The third step is to develop a plan or strategy to address the problem. This involves breaking down the problem into smaller, manageable tasks and determining the resources needed to complete them.

4. The fourth step is to implement the plan. This involves putting the strategy into action and monitoring progress to ensure that the project is on track.

5. The final step is to evaluate the results of the project. This involves assessing the outcomes against the objectives and goals and identifying any lessons learned for future projects.

[illegible]

## SECT. XL.

## OF LICHENS.

Lichens are a class of plants which differ almost in every respect from other vegetables. Many of them are not the smallest appearance of plants, but form crusts, which cover rocks, wood, trees, &c.; others are the form of leaves or of branches, but nothing resembling flowers is visible. It was to Tournefort and Delile that botany is indebted for first fixing the *lichen*, formerly vague and ill defined, to a peculiar set of plants. Afterwards Linnaeus placed them among the algae, and described 81 species. Since that time a great variety of botanical writers have devoted considerable attention to them, particularly in ascertaining and describing their parts of fructification, and various changes which they undergo in the different periods of their vegetation; but few only have attempted to analyse them, or to point out the useful purposes to which they may be applied. Willemet has given us a historical account of 41 species of lichens, detailed their medical and economical uses with considerable accuracy. Amoreux, in a dissertation on this subject, has given us still more copious details, has published likewise a brief chemical analysis of some of the most remarkable lichens. Hoffmann, who has previously distinguished himself by his botanical nomenclature of the lichens, published an account of

Book IV.

their chemical and economical properties in 1787, and has given us the chemical analysis of several, made by Georgi with considerable care. Westring turned his attention particularly to the uses of the lichens in dyeing; and in seven dissertations, published successively in the Stockholm Transactions from 1792 to 1797, has examined almost all the lichens of the north, and described the colours which each of them is capable of yielding, and the manner of obtaining it. It is to these writers and to Georgi, that we are indebted for the few facts known respecting the composition and chemical properties of the lichens.

The lichens are found in all countries and climates, and are very numerous; considerably more than 1000 hundred species have been described by botanists as natives of Britain.

Some lichens contain gum.

From the experiments of Georgi, professor of chemistry in Petersburg, we learn that the lichen *furcaceus*, *glaucus*, and *physodes*, form with water a mucilage which yields, when evaporated, a gum as transparent and tasteless as gum arabic. Lichen *pulmonarius* yields likewise a gum, but its taste is somewhat bitter. The gum yielded by these lichens amounted to  $\frac{1}{4}$ th of their weight. When treated with alcohol, the liquid acquires a green colour and a bitter taste\*. Amoreux, who repeated these experiments, obtained from the lichen *pulmonarius* a reddish gum, much less transparent than gum arabic. This lichen gave a yellow colour to alcohol. Probably he had examined a different

---

\* See the experiments of Georgi, as quoted by Amoreux, in his *Recherches et Experiences sur les divers Lichens*, p. 94.



species from that tried by Georgi, or if not, the lichens must have been of very different ages.

Amoreux found, that when the lichen *prunastri* was steeped in water, its branches became transparent like animal membrane, and adhered strongly to paper. In this state it is insipid, but as friable as celery. He obtained abundance of gum from the lichen *islandicus*, and from all the broad-leaved lichens tried. He succeeded in extracting gum from the lichen *fraxineus*, *canninus*, and *caperatus*. This last gave a lemon yellow colour to ammonia\*.

Georgi found, that when the lichen *physodes*, *hirtus*, *farinaceus*, and *pulmonarius*, were boiled in water, they yielded a yellowish mucilage nearly insipid, and that the lichens thus treated might be eaten with salt. They all yielded a portion of resin to alcohol, but it did not taste the water in which they were boiled. When incinerated, these lichens yielded a little potash, lime, and silica, but no sulphuric or muriatic salt. When distilled, they yielded an acidulous water, and a yellow or blackish oil which sunk in water.

Some may  
be used as  
food.

Such are the imperfect experiments hitherto made on the constituents of a few of the lichens. I shall now mention such of them as are most remarkable for the colouring matters which they yield.

1. *Lichen roccella*.—This lichen which grows abundantly in the Canary islands, but which is found also on the south coast of England and France, yields the dye stuff called *archil*. If we believe Tournefort, this dye stuff was known to the ancients, and was employed to

Archil.

\* See the experiments of Georgi, as quoted by Amoreux in his *Recherches et Expériences sur les divers Lichens*, p. 95.

3. *Lichen pertusus*.—Treated with lime and sal-ammoniac, it yielded a brown colouring matter to Westring.

Chap. II.  
Other lichens yielding colouring matters.

4. *Lichen ventosus*.—This lichen dyed wool of a brown colour, which resisted the action of alkalies.

5. *Lichen barmatoma* yielded a wax yellow colour.

6. *Lichen corralinus*.—This lichen was found by Westring to abound in colouring matter. By simple infusion in water with a little common salt, it dyed wool yellow. Without addition, it gives a deep brown of considerable permanence. It yielded the same colour when treated with sal-ammoniac and lime.

7. *Lichen pseudo-coralinus* yielded a fine orange, which was brightened by muriate of cobalt.

8. *Lichen tartareus* yielded a fine brown.

9. *Lichen centrifugus*, with fixed alkalies, yielded a fine wax yellow; with water, a brown; with common salt and nitre, an orange.

10. *Lichen saxatilis*.—This lichen, with soda, yields a yellow; with lime and sal-ammoniac, a nankeen; and with muriate of soda and nitre, an orange.

11. *Lichen physodes*, by the same reagents, yields various shades of yellow and brown; *lichen juniperinus*, yellow and brown; *lichen tenellus*, yellow, olive, and reddish brown; *lichen furfuraceus*, yellow and brown. The same colours were obtained from a considerable number of leafy lichens.

*Lichen croceus*, with lime and sal-ammoniac, gave out a red colour. Westring obtained several colours from other lichens; and by mixing several of them together, he varied the shade, and produced a new set of colours, differing both in their intensity and fixity. But for the particulars of his numerous experiments,

Book IV. the reader is referred to his dissertations on the subject\*.

---



---

## SECT. XII.

### OF MUSHROOMS.

THE mushrooms are a class of plants proverbial for the rapidity of their growth and their speedy decay. When they putrefy, they give out an extremely unpleasant odour, and appear to approach animal matter much more closely than other vegetable substances. A chemical analysis of the more remarkable species would be curious, and would probably make us acquainted with several new substances; but hitherto, as far as I know, the following species only have been chemically examined.

*Boletus laticia.*

1. *Boletus laticia*.—This plant, in a dry state, is used on the continent as a medicine, and sold under the name of *agaric*. It has been lately examined by Bouillon La Grange†.

It is in pieces, which are white, light, and friable. The outer skin is leathery and dark-coloured. Its taste is at first sweetish, but it leaves a bitter and acrid

---

\* The first has been translated into French, and printed in vols. xv. and xvii. of the *Annales de Chimie*. The others are inserted in Crell's *Annals* for 1796, 1797, and 1799.

† *Ann. de Chim.* li. 76.

sion in the mouth. When steeped in water, it communicates a yellowish colour and a sweetish taste to the liquid. The infusion reddens vegetable blues; it dissolves in solution sulphate of potash, sulphate of soda, and muriate of potash.

When this substance is boiled in water, the liquid assumes a gelatinous form as it cools. Evaporated to dryness, and treated with lime, the odour of ammonia becomes perceptible. Alcohol, boiled upon the boletus, assumes a red colour; and when mixed with water, it yields a copious precipitate, which exhibits the properties of a resin. This resin has a yellow colour, is semitransparent, and has a sour and bitter taste. When treated with lime, and the solution afterwards exposed to muriatic acid, a quantity of benzoic acid is obtained from it. From these experiments, it is evident that this substance contains resin, benzoic acid, different salts, some extractive, and some animal matter, to which the gelatinous form of the decoction must be ascribed.

Phosphoric acid dissolves and rapidly chars the boletus. Nitric acid acts with energy; nitrous gas is disengaged, and the boletus becomes brown. By continuing the action of the acid, crystals of oxalic acid are obtained; benzoic acid is likewise formed, together with some red substance which approaches the nature of galls in its properties. The fixed alkalies give it a red colour, render it gelatinous, and a great quantity of ammonia is disengaged\*.

*Boletus igniarius*.—This boletus is not uncommon.

*Boletus igniarius.*

\* Bouillon la Grange, *Ann. de Chim.* li. 76.

THE ... A variety ... countries as ... by boiling it in ... becomes soft ... boiling; a second time in the ... was recommended by Bros- ... excellent syrup; and va- ... France and Bri- ... a chemical ex- ...

What ... deep ... holds ... of lime and ... of potash. ... colour- ... white ... portion of ... water, exhibited, by ... the ... of muriatic and ... acid. The ... portion of the boletus, being ... was found to contain phosphates of lime and ... and some iron.

Alcohol has scarcely any action on this ...; but when assisted by heat, it dissolves a small portion of ... Nitric acid dissolves it readily; malic and ox-  
alic acids are formed, and probably also a portion of  
bitter principle, while carbonic acid and nitrogen  
are disengaged. Alkaline leys dissolve it with dif-  
ficulty; forming, however, a soapy liquid, and separ-  
ating a small portion of ammonia. From these experi-



ments, we learn that this *boletus* differs in many respects from the preceding. It contains much less resin, and a much smaller proportion of animal matter, and yields no traces of benzoic acid \*.

Chap. II.

3. *Lycoperdon tuber*, or *tuber cibarium*; *truffles*.—This is a globular fungus found four or five inches under ground, in woody places, and is considered as one of the best of the edible mushrooms. Bouillon la Grange has lately subjected it to a chemical analysis †. It was attempted nearly in the manner formerly described for ascertaining the constituents of the different species of corn.

Truffles.

It was grated down small, and then washed with water upon a searce, till the liquid ceased to carry off any thing. A blackish fibrous matter remained upon the searce. The liquid let fall a brown coloured matter when left at rest. The liquid produced no effect upon vegetable blues. The brown deposit does not resemble starch in its properties. Water produces but little effect upon truffles. Warm water, however, dissolves a portion, which possesses the characters of albumen.

When the plant was treated with nitric acid, a solution was accomplished; nitrous gas, carbonic acid, and azotic gas were disengaged; and the solution, by distillation, yielded a liquor containing prussic acid. The residual liquid yielded bitter principle, an oily matter, and small crystals, which Bouillon la Grange considered as a combination of oxalic acid and bitter principle. He suspected also the presence of malic acid.

\* Bouillon la Grange, *Ann. de Chim.* liv. 92.

† *Ann. de Chim.* xlv. 197.

Book IV.

Alcohol dissolves a small portion of brownish bitter matter, which acquires the properties of resin by exposure to the atmosphere.

When truffles are left in the state of a paste with water, they acquire the smell of cheese. When mixed with sugar and water they undergo fermentation, carbonic acid is disengaged, and alcohol formed.

When distilled, truffles yield an acid liquid, a black oil, carbonate of ammonia, carbonic acid, and carbureted hydrogen. The charcoal contains magnesia, phosphate of lime, iron, and silica \*.

Several experiments have been likewise made upon this plant by Robert and Antoine, which confirm those of Bouillon la Grange.

Agaricus  
piperatus.

4. *Agaricus piperatus*.—From the observations of Trommsdorf, we learn that this plant contains a great portion of a peculiar acrid matter, and abundance of albumen. When distilled it yields a considerable quantity of carbonate of ammonia †. This mushroom was examined by Dr Lister, and the result published in the Philosophical Transactions for 1672 ‡. He found them to yield a milky juice with a taste hotter than pepper, not discoloured by exposure to the air, nor by the blade of a knife. This juice speedily coagulated when kept in a glass vessel, but did not lose its hot taste.

Though this is the only species of the numerous family of agarics hitherto subjected to chemical analysis, many others are highly deserving of attention. The *agaricus campestris*, *coriacius*, *deliciosus*, and a few

\* Bouillon la Grange, *Ann. de Chim.* xlv. 197.

† *Ann. de Chim.* xlii. 220. ‡ Vol. vii. p. 5116.

thers, are very commonly served up as an article of food, and form the basis of various sauces. Other species of *agaricus*, as the *muscarius*, *piperatus*, &c. possess very deleterious qualities.

The same remarks apply to the different species of *oleti*. Much curious information might be expected from the analyses of the *phallus esculentus* and the *phallus impudicus*, so remarkable for the abominable odour which it diffuses all around, and for the suddenness with which it runs to putrefaction.

---

### SECT. XIII.

#### OF THE DISEASES OF PLANTS.

HAVING now given such an account of the parts of plants as the present imperfect state of vegetable chemistry permitted, it remains for us to point out the new substances generated in plants by disease, and to describe the properties of these substances. But though the diseases of plants are numerous and well marked, and though the effects which they produce on those vegetables which are employed as articles of food are often severely felt, yet little progress has been made, either in ascertaining the nature of these diseases, or in the method of preventing or removing them. The following are the only observations, strictly chemical, which can be at present offered :



Book IV.  
Ulcers.

1. Old trees are frequently affected with a kind of ulcer, the chief seat of which is under the bark. There the juices undergo a change, and acquire a certain acridity, which enables them to corrode and destroy the solid parts of the plant. We are indebted to Vauquelin for an examination of the sanies or morbid liquid which flows from the ulcer in these cases. He collected the matter which he examined from the elm, which is particularly subject to this disease\*.

This liquor is sometimes nearly transparent like water, and having an acrid and saline taste; sometimes it is slightly coloured, sometimes blackish or brown. It deposits upon the sides of the ulcer a soft matter, which is insoluble in water. The bark over which the transparent sanies passes becomes white like chalk, acquires an alkaline taste, and effervesces powerfully with acids. It becomes friable, loses its fibrous texture, and exhibits the appearance of crystals. By means of a glass small rhomboids and four-sided prisms can be distinguished in it. When the liquid is dark coloured, the bark assumes a black appearance, and looks as if covered with a coat of varnish. This black matter is sometimes in such quantity that it assumes the appearance of stalactites. It is soluble in water, has an alkaline taste, and effervesces with acids.

The white matter which was deposited on the bark of the elm round the ulcer, was found composed of

---

\* *Ann. de Chim.* xli. 39.

60.5 vegetable matter  
 34.2 carbonate of potash  
 5.0 carbonate of lime  
 0.3 carbonate of magnesia

Chap. II.

---

100.0

black shining matter consisted of carbonate of and a peculiar substance which possessed most properties of *gum*, though it differed from that in several particulars.

destructive tendency of such ulcers in trees is very obvious. Vauquelin has shown, that to the quantity of white matter which surrounded of the elm, and on which he made his experiment 500 lbs weight of the wood of the tree must be destroyed\*.

The blight is a disease which attacks the different parts of corn, especially wheat, and in some seasons destroys the crop. It begins first upon the lower stem, and at last, attacking the seed, destroys the valuable part, or even the whole of it, leaving a hollow in its place. Botanists have shown, that the matter is a species of small fungus, which deprives the wheat of nourishment from the wheat†. The wheat infected with the black fungus has been lately examined by Fourcroy and Vauquelin, in order to ascertain the experiments of former chemists were correct. The result of their examination has been published.

Blight in wheat.

\* *Chim.* xxi. 39.

† account of this fungus, with figures of it, and ingenious respecting its propagation, by Sir Joseph Banks. Nicholson's



## DISEASES OF PLANTS.

In the 18th volume of the *Annales de Museum*  
*Naturalis* \*.

The wheat was macerated with alcohol, it gave a solution of acrid oil, of the consistence of butter, and a green colour. Water in which it was steeped acquired acidity, and when saturated with potash let it in animal matter, mixed with phosphate of ammonia and magnesia, and held phosphate of potash in solution. Of course, the acid which it contained was the phosphoric. It still retained in solution a matter similar to gluten of wheat allowed to run into putrefaction. The residue, distilled, yielded water, holding in solution acetic acid and acetate of ammonia, a brown oil, and a quantity of charcoal, amounting to nearly  $\frac{1}{4}$ th of the original weight. The result of the experiments was, that blighted wheat contained an acrid oil, putrid gluten, charcoal, phosphoric acid, phosphate of magnesia and ammonia, and phosphate of lime; but no traces of starch could be detected.

3. Barley is subject to a similar disease with wheat, and, doubtless, from the same cause. Einhof has lately subjected this grain, damaged by the *rubigo*, or blight, to a chemical examination. The result of his trials coincides pretty nearly with the experiments of Fourcroy and Vanquelin on blighted wheat. He could detect no starch in it. The infusion of it in water reddened vegetable blues, and contained an acid, which appeared to be the phosphoric. There was present a peculiar animal matter, differing in its properties from any of the principles of barley, and a quantity of charcoal †.

\* No. XXV. p. 332.

† Gehlen's *Jour.* vi. 91.

---

**CHAP. III.****OF VEGETATION.**  

---

have now seen the different substances which are  
ed in plants, and of which they are composed :  
have still to examine the manner in which these  
ces are produced, and to endeavour to trace the  
at processes which constitute vegetation. But I  
warn the reader not to expect complete informa-  
this Chapter. The wonders of the vegetable  
m are still but very imperfectly explored ; ma-  
the organs of plants are too minute for our sen-  
ad scarcely a single process can be completely

multiplicity of operations continually going on  
tables at the same time, and the variety of dif-  
and even opposite substances, formed out of the  
agredients, and almost at the same place, astonish  
around us. The order, too, and the skill with  
every thing is conducted, are no less surprising.  
o operations clash ; there is no discord, no irregu-  
no disturbance ; every object is gained, and eve-  
g is ready for its intended purpose. This is too  
ful to escape our observation, and of too much  
ance not to claim our attention. Many philoso-

Book IV.

phers, accordingly, distinguished equally by their industry and sagacity, have dedicated a great part of their lives to the study of *vegetation*. But hitherto their success has not been equal to their exertions. No person has been able to detect this *Agent*, always so busy, and performing such wonders, or to discover him at his work ; nor have philosophers been much more fortunate in their attempts to ascertain the instruments which he employs in his operations. A great variety, however, of curious and interesting facts have been discovered. These I shall attempt in the following Sections to collect and arrange, to point out their dependence on each other, and perhaps to deduce such consequences as obviously result from this mutual dependence.

---



---

## SECT. I.

### OF GERMINATION.

Plants produced from seeds.

1. NATURAL historians have proved, by a very complete induction of facts, that all plants arise from *seeds*. The pretended exceptions have disappeared, one after another, as our knowledge of vegetables increased : and now there remains scarcely a single objection entitled to the smallest regard. The late attempt of Girtanner\* to revive the doctrine of equivocal generation, deserves no attention whatever ; because his conclusions are ab-

---

\* *Ann. de Chim.* xxxiv. 35.

ately incompatible with the *experiments* of Mr Senne-  
er upon the very substance on which his theory is  
founded.

Chap. III

A SEED consists of three parts: namely, the *cotyle-*  
*on*, the *radicle*, and the *plumula*, which are usually in-  
closed in a cover.

Seeds com-  
posed of  
three parts;

If we take a garden bean, we may perceive each of  
these three parts with great ease; for this seed is of so  
large a size, that all its organs are exceedingly distinct.  
When we strip off the external coats of the bean, which  
are two, and of different degrees of thickness in differ-  
ent parts, we find that it easily divides into two lobes,  
pretty nearly of the same size and figure. Each of  
these lobes is called a *cotyledon* (fig. 40. *a*). The coty-  
ledons of the bean, then, are two in number.

viz. Coty-  
ledon,

Near that part of the lobes which is contiguous to  
that is called the *eye* of the bean, there is a small round  
white body (*b*), which comes out between the two  
lobes. This body is called the *radicle*.

Radicle,

Attached to the radicle there is another small round  
body (*c*), which lies between the cotyledons, and whol-  
ly within them, so that it cannot be seen till they are  
separated from each other. This body is called the  
*plumula*.

Plumula.

The appearance and shape of these three parts differ  
much in different seeds, but there is no seed which  
lacks them. The figure and size of the seed depend  
upon the cotyledons. This is evidently the case  
in the bean, and it is so with all other seeds. The  
number of cotyledons is different in different seeds.  
Some seeds have only one cotyledon, as the seeds of  
oats, barley, and the whole tribe of grasses;  
others three; others six, as the seeds of the garden

Book IV. cress ; but most seeds, like the bean, have two cotyledons.

Germination

2. When a seed is placed in a situation favourable to vegetation, it very soon changes its appearance. The radicle is converted into a root, and sinks into the earth, the plumula on the other hand, rises above the earth, and becomes the trunk or stem. When these changes take place, the seed is said to *germinate* : the process itself has been called *germination*. Seeds do not germinate equally and indifferently in all places and seasons. Germination, therefore, is a process which does not depend upon the seed alone : something external must also affect it.

Requires moisture,

3. It is a well known fact, that seeds will not germinate unless *moisture* have access to them ; for seeds, if they are kept perfectly dry, never vegetate at all, and yet their power of vegetating is not destroyed. *Water*, then, is essential to germination. Too much water, however, is no less prejudicial to most seeds than none at all. The seeds of water plants, indeed, germinate and vegetate extremely well in water ; but most other seeds, if they are kept in water beyond a certain time, are rotted and destroyed altogether.

Heat,

4. It is well known also, that seeds will not germinate, even though supplied with water, provided the temperature be below a certain degree. No seed, for instance, on which the experiment has been tried, can be made to vegetate at or below the freezing point : yet this degree of cold does not injure the vegetating power of seeds ; for many seeds will vegetate as well as ever after having been frozen, or after having been kept in frozen water. We may conclude, then, that a certain degree of heat is necessary for the germination of seeds :



every species of plant seems to have a degree peculiar to itself, at which its seeds begins to germinate; every seed has a peculiar season at which it begins to germinate, and this season varies with the temperature of the air. Mr Adanson found that seeds, when sown at the same time in France and in Senegal, always sprang sooner above ground in the latter country, because the climate is hotter than in France \*.

Chap. III.

Seeds, although supplied with moisture and placed in a proper temperature, will not germinate, provided atmospheric air be completely excluded from them.

And oxygen gas.

Mr Ray found that grains of lettuce did not germinate in the vacuum of an air pump, but they began to grow as soon as air was admitted to them †. Homberg made a number of experiments on the same subject, which were published in the Memoirs of the French Academy for the year 1693. He found, that a greater number of seeds which he tried refused to germinate in the vacuum of an air-pump. Some, however, did germinate: but Boyle, Muschenbroeck, and Van Leeuwenhoek, who made experiments on the same subject in succession, proved beyond a doubt that no plant vegetates in the vacuum of an air-pump; and that in the cases in which Homberg's seeds germinated, the vacuum was far from perfect, a quantity of air still remaining in the receiver. It follows, therefore, that no seeds will germinate unless atmospheric air, or some gas having the same properties, have access to it. It is for this reason that seeds will not germinate at a certain depth below the surface of the earth.

\* *Encyc. Method. Physiol. Veget.* 124.    † *Phil. Trans.* No. lili.

VEGETATION.

Mr. Schenk found that there could not be  
any other origin for vegetation. Mr. A. had  
found, however, that the vegetation was  
produced in all cases, in nature and in  
artificially, by the action of the sun, of the  
water, and of the air. He found that the  
vegetation was produced in all cases by the  
action of the sun, of the water, and of the  
air. He found that the vegetation was  
produced in all cases by the action of the  
sun, of the water, and of the air.

He found that the vegetation was produced  
in all cases by the action of the sun, of the  
water, and of the air. He found that the  
vegetation was produced in all cases by the  
action of the sun, of the water, and of the  
air. He found that the vegetation was  
produced in all cases by the action of the  
sun, of the water, and of the air.

He found that the vegetation was produced  
in all cases by the action of the sun, of the  
water, and of the air. He found that the  
vegetation was produced in all cases by the  
action of the sun, of the water, and of the  
air. He found that the vegetation was  
produced in all cases by the action of the  
sun, of the water, and of the air.

He found that the vegetation was produced  
in all cases by the action of the sun, of the  
water, and of the air. He found that the  
vegetation was produced in all cases by the  
action of the sun, of the water, and of the  
air. He found that the vegetation was  
produced in all cases by the action of the  
sun, of the water, and of the air.

jected to the conclusions of these philosophers, and affirmed that the difference in the germination of seeds in the shade and in the light was owing, not to the light itself, but to the difference in the moisture in the two situations; the moisture evaporating much faster from the seeds in the light than from those in the shade; and he affirmed, that when precautions were taken to keep the seeds equally moist, those in the sun germinated sooner than those in the shade\*. But when Mr Sennebier repeated his former experiments, and employed every possible precaution to ensure the equality of moisture in both situations, he constantly found the seeds in the shade germinate sooner than those in the light†. We may conclude, therefore, that light is injurious to germination; and hence one reason for covering seeds with the soil in which they are to grow. But from the recent experiments of Saussure, there is reason to believe that light is only injurious in consequence of the heat which it produces; for when the direct rays of the sun were intercepted, though light was admitted, the germination of the seeds was not sensibly retarded‡.

7. Thus we have seen that seeds will not germinate unless *moisture*, *heat*, and *oxygen* be present. Now, in what manner do these substances affect the seed? What are the changes which they produce?

It was observed before, that all seeds have one or more cotyledons. These cotyledons contain a quantity of farinaceous matter, laid up on purpose to supply the

Phenomena  
of germina-  
tion.

\* *Jour. de Phys.* 1789, December.

† *Encyc. Meth. Physiol. Veget.* 126.

‡ *Recherches Chimiques sur la Végétation*, p. 23.

**Book IV.** embryo plant with food as soon as it begins to require it. This food, however, must undergo some previous preparation, before it can be applied by the plant to the formation or completion of its organs. It is probable that all the phenomena of germination, which we can perceive, consist in the chemical changes which are produced in that food, and the consequent development of the organs of the plant.

Carbonic  
acid emit-  
ted.

When a seed is placed in favourable circumstances, it gradually imbibes moisture, and very soon after emits a quantity of carbonic acid gas, even though no oxygen gas be present\*. If no oxygen gas be present, the process stops here, and no germination takes place; but if oxygen gas be present, a portion of it is converted into carbonic acid gas. From the experiments of Saussure, it appears, that if seeds be left to germinate in a determinate portion of oxygen gas or common air, the bulk of that gas is not altered; the carbonic acid formed being equal to the oxygen which has disappeared. Hence it follows, that the carbonic acid contains in it exactly the whole oxygen consumed†. No oxygen, then, is absorbed by the seed; or at least, if it be absorbed, none of it is retained, the whole being thrown out in combination with carbon. The quantity of oxygen thus changed into carbonic acid by the germination of seeds, is in some measure proportional to the weight of the seed; but some seeds require more than others. In the experiments of Saussure, wheat and barley, weight for weight, consumed less oxygen than peas; while peas consumed less than beans and kidney-beans. The

Oxygen of  
the air di-  
minished.

\* Gough, *Manch. Mem.* iv. 315.—Cruikshank, *Rolls on Diet*, p. 452.  
† *Jour. de Phys.* xlix. 92.



oxygen consumed by wheat and barley amounts to between  $\frac{1}{1000}$ th and  $\frac{1}{500}$ th of their weight; while that consumed by beans and kidney-beans may amount to  $\frac{1}{100}$ th part of their weight\*. Similar experiments were made by Dr Woodhouse†.

It does not appear that any water is decomposed during the process of germination, at least we have no evidence that it is so. Neither hydrogen nor oxygen gas are emitted. It would not be surprising if a portion of water, so far from being decomposed, were actually formed by the union of its constituents previously existing in the grain. When Saussure dried seeds at a certain temperature before germination, and afterwards brought them to the same degree of dryness after germination, he always found that the loss of weight was greater than it ought to have been. Thus 73 peas, which together (when dried at  $77^{\circ}$ ) weighed 200 grains, when left with five times their weight of water in a vessel full of air, and standing over mercury for two days, germinated, and produced  $4\frac{1}{2}$  cubic inches of carbonic acid. They were taken out, and dried slowly at the same temperature; during their drying they changed  $4\frac{1}{2}$  cubic inches more of oxygen into carbonic acid. Now these nine inches of carbonic acid contain 1.7 grains of carbon. The water in which peas had been placed while germinating, when evaporated to dryness, left 0.75 grains of mucilaginous matter. Thus the peas, by germinating and drying, ought to

\* Berberber, p. 13.

† He tried the seeds of the zea mays, opium petroselinum, lactuca sativa, cucurbita citrulla, phaseolus sativus, elisymbrium sativum, raphanus sativa. They changed oxygen into carbonic acid. Nicholson's Jour. ii. 167.



Book IV.

have lost only 2.45 grains, leaving a residue of 197.55 grains. But their weight was only 189 grains. So that they had lost eight grains more than can be accounted for by the mucilage taken up by the water and carbonic acid formed. We are obliged to suppose this loss owing to water. From Saussure's experiments, this water seems to be formed or set at liberty during the drying of the seeds, for the quantity of it always increased with the slowness of the process of drying\*.

Food prepared in the cotyledons.

Several seeds, by germinating, acquire a sweetish taste. Hence it has been supposed, that the mucilage which they contain is converted into saccharine matter. We see that the carbon is diminished by germination; and unless water be formed, the proportion of hydrogen and oxygen must be proportionably augmented. It is obvious from the process of malting, that heat is generated during germination. I have seen the radicles of barley, when kept without turning on the malt-floor, shoot out half an inch in a single night, and the heat rise as high as 100°.

So far seems to be the work of chemistry alone; at least we have no right to conclude that any other agent interferes; since *hay*, when it happens to imbibe moisture, exhibits nearly the same processes. Carbonic acid gas is evolved, oxygen gas is absorbed, heat is produced so abundantly, that the hay often takes fire: at the same time a quantity of sugar is formed. It is owing to a partial change of the same kind that old hay generally tastes much sweeter than new hay. Now we have no reason to suppose that any agents peculiar to the

\* Saussure, *Recherches Chimiques sur la Végétation*, p. 17.

vegetable kingdom reside in hay; as all vegetation, and all power of vegetating, are evidently destroyed.

But when the farina in the seeds of vegetables is converted into sugar, a number of vessels make their appearance in the cotyledon. The reader will have a pretty distinct notion of their distribution by inspecting fig. 41. These vessels may indeed be detected in many seeds before germination commences, but they become much more distinct after it has made some progress. Branches from them have been demonstrated by Grew, Malpighi, and Hedwig, passing into the radicle, and distributed through every part of it. These evidently carry the nourishment prepared in the cotyledons to the radicle; for if the cotyledons be cut off, even after the processes above described are completed, germination, as Bonnet and Sennebier ascertained by experiment, immediately stops. The food therefore is conveyed from the cotyledons into the radicle; the radicle increases in size, assumes the form of a root, sinks into the earth, and soon becomes capable of exerting the nourishment necessary for the future growth of the plant. Even at this period, after the radicle has become a perfect root, the plant, as Sennebier ascertained by experiment, ceases to vegetate if the cotyledons be cut off. They are still, then, absolutely necessary to the vegetation of the plant.

And sent into the radicle,

Which becomes a root.

The cotyledons now assume the appearance of leaves, and appear above the ground, forming what are called seminal leaves of the plant. After this the plumula gradually increases in size, rises out of the earth, and divides itself into branches and leaves. The seminal leaves soon after this, decay and drop off, and the plant

Seminal leaves

Bo. IV. carries on all the processes of vegetation without their assistance.

Digest the  
food sent  
by the root.

As it does not appear that there is any communication between the cotyledons and the plumula, it must follow that the nourishment passes into the plumula from the radicle; and accordingly we see that the plumula does not begin to vegetate till the radicle has made some progress. Since the plant ceases to vegetate, even after the radicle has been converted into a root, if the cotyledons be removed before the plumula is developed, it follows that the radicle is insufficient of itself to carry on the processes of vegetation, and that the cotyledons still continue to perform a part. Now we have seen already what that part is; they prepare food for the nourishment of the plant. The root, then, is of itself insufficient for this purpose. When the cotyledons assume the form of seminal leaves, it is evident that the nourishment which was originally laid up in them for the support of the embryo plant is exhausted, yet they still continue as necessary as ever. They must therefore receive the nourishment which is imbibed by the root; they must produce some changes on it, render it suitable for the purposes of vegetation, and then send it back again to be transmitted to the plumula.

After the plumula has acquired a certain size, which must be at least a *line*, if the cotyledons be cut off, the plant, as Mr Bonnet ascertained by a number of experiments afterwards repeated with equal success by Mr Sennebier, does not cease to vegetate, but it continues always a mere pigmy: its size, when compared with that of a plant whose cotyledons are allowed to remain being only as two to seven\*.

---

\* *Encyc. Method. Physiol. Veget.* 42.

When the plumula has expanded completely into leaves, the cotyledons may be removed without injuring the plant, and they very soon decay of themselves. It appears, then, that this new office of the cotyledons is afterwards performed by that part of the plant which is above ground.

Thus we have traced the phenomena of germination as far as they have been detected. The facts are obvious; but the *manner* in which they are produced is a profound secret. We can neither explain how the food enters into the vessels, how it is conveyed to the different parts of the plant, how it is deposited in every organ, nor how it is employed to increase the size of the old parts, or to form new parts. These phenomena are analogous to nothing in mechanics or chemistry, but resemble exactly the organization and nourishment of animals. They belong therefore to that difficult branch of science known by the name of *PHYSIOLOGY*.

## SECT. II.

### OF THE FOOD OF PLANTS.

PLANTS, after they have germinated, do not remain stationary, but are continually increasing in size. A tree, for instance, every season adds considerably to its former bulk. The root sends forth new shoots, and the old ones become larger and thicker. The same increment takes place in the branches and the trunk. When



Book IV;

we examine this increase more minutely, we find that a new layer of wood, or rather of alburnum\*, has been added to the tree in every part, and this addition has been made just under the bark. We find, too, that a layer of alburnum has assumed the appearance of perfect wood. Besides this addition of vegetable fibre, a great number of leaves have been produced, and the tree puts forth flowers, and forms seeds.

Plants require food.

It is evident from all this, that a great deal of new matter is continually making its appearance in plants. Hence, since it would be absurd to suppose that they *create* new matter, it must follow that they receive it by some channel or other. Plants, then, require food as well as animals. Now, what is this food, and whence do they derive it? These questions can only be answered by an attentive survey of the substances which are contained in vegetables, and an examination of those substances which are necessary for their vegetation. If we could succeed completely, it would throw a great deal of light upon the nature of soils and of manures, and on some of the most important questions in agriculture. But we are far indeed at present from being able to examine the subject to the bottom.

Water necessary.

1. In the first place, it is certain that plants will not vegetate without water; for whenever they are deprived of it, they wither and die. Hence the well-known use

---

\* The *wood*, when we inspect it with attention, is not, through its whole extent, the same; the part of it next the bark is much softer and whiter, and more juicy than the rest, and has for that reason obtained a particular name; it has been called the *alburnum* or *aubier*. The *perfect wood* is browner, and harder, and denser than the *alburnum*, and the layers increase in density the nearer they are to the centre.

of rains and dews, and the artificial watering of ground. Water, then, is at least an essential part of the food of plants. But many plants grow in pure water; and therefore it may be questioned whether water is not the only food of plants. This opinion was adopted very long ago, and numerous experiments have been made in order to demonstrate it. Indeed it was the general opinion of the 17th century; and some of the most successful improvers of the physiology of plants, in the 18th century, have embraced it. The most zealous advocates for it were, Van Helmont, Boyle, Bonnet, Duhamel, and Tillet. Chap. III.

Van Helmont planted a willow, which weighed five pounds, in an earthen vessel filled with 200 lbs of soil previously dried in an oven, and moistened with rain water. This vessel he sunk into the earth, and he watered his willow, sometimes with rain, and sometimes with distilled water. After five years it weighed 169½ lbs, and the earth in which it was planted, when again dried, was found to have lost only two ounces of its original weight\*. Here, it has been said, was an increase of 164 lbs. and yet the only food of the willow was pure water; therefore it follows that pure water is sufficient to afford nourishment to plants. The insufficiency of this experiment to decide the question was first pointed out by Bergman in 1773†. He showed, from the experiments of Margraf, that the rain water employed by Van Helmont contained in it as much earth as could exist in the willow at the end of five years. For, according to the experiments of Margraf, one

Supposed  
the sole  
food of  
plants;

\* *Opera* Van Helmont, p. 105. *Complexionum atque Mitionum Elementarium Figmentum*, sect. 30.

† *Opera*. v. 92.

Book IV.

But without  
reason.

pound of rain water contains one grain of earth \*. The growth of the willow, therefore, by no means proves that the earth which plants contain has been formed out of water. Besides, as Mr Kirwan has remarked †, the earthen vessel must have often absorbed moisture from the surrounding earth, impregnated with whatever substance the earth contained; for unglazed earthen vessels, as Hales ‡ and Tillet § have shown, readily transmit moisture. Hence it is evident, that no conclusion whatever can be drawn from this experiment; for all the substances which the willow contained, except water, may have been derived from the rain water, the earth in the pot, and the moisture imbibed from the surrounding soil.

The experiments of Duhamel and Tillet are equally inconclusive; so that it is impossible from them to decide the question, Whether water be the sole nourishment of plants or not? But all the attempts hitherto made to raise plants from pure water have failed; the plants vegetating only for a certain time, and never perfecting their seeds. These experiments were made by Hassenfratz, Saussure, and others, with the same unfavourable result. Duhamel found, that an oak which he had raised by water from an acorn made less and less progress every year. We see, too, that those bulbous roots, such as hyacinths, tulips, &c. which are made to grow in water, unless they be planted in the earth every other year, refuse at last to flower, and even to vegetate; especially if they produce new bulbous roots annually, and the old ones decay. From all

\* *Opusc.* ii. 15. and 19.† *Veget. St. It.*‡ *Irish Trans.* v. 160.§ *Mem. Par.* 1772, 29

### FOOD OF PLANTS.

these facts and experiments, it is reasonable to conclude that water is not the sole food of plants \*.

So far, indeed, is water from being the sole food of plants, that in general only a certain proportion of it is serviceable, too much being equally prejudicial to them as too little. Some plants, it is true, grow constantly in water, and will not vegetate in any other situation; but the rest are entirely destroyed when kept immersed in that fluid beyond a certain time. Most plants require a certain degree of moisture in order to vegetate well. This is one reason why different soils are required for different plants. Rice, for instance, requires a very wet soil: Were we to sow it in the ground on which wheat grows luxuriously, it would not succeed; and wheat, on the contrary, would rot in the rice ground.

We should, therefore, in choosing a soil proper for the plants which we mean to raise, consider the quantity of moisture which is best adapted for them, and choose our soil accordingly. Now the dryness or moisture of a soil depends upon two things; the nature and proportions of the earths which compose it, and the quantity of rain which falls upon it. Every soil consists at least three earths, silica, lime, and alumina, and sometimes also magnesia. The silica is always in the form of sand. Now soils retain moisture longer or

---

\* The late experiments of Braconnot, who has endeavoured to prove that water is the sole food of plants, are by no means decisive. See *Ann. Chim.* 187. He raised plants on sand and metallic oxides by means of water, and found that the plants had all the usual vegetable, earthy, and saline constituents. But in experiments of that nature it is impossible to guard against every channel, by means of which these substances may have access to plants.



## Book IV.

shorter according to the proportions of these earths. Those which contain the greatest quantity of sand retain it the shortest, and those which contain the greatest quantity of alumina retain it longest. The first is a dry, the second a wet soil. Lime and magnesia are intermediate between these two extremes: they render a sandy soil more retentive of moisture, and diminish the wetness of a clayey soil. It is evident, therefore, that by mixing together proper proportions of these four earths, we may form a soil of any degree of dryness and moisture that we please.

But whatever be the nature of the soil, its moisture must depend in general upon the quantity of rain which falls. If no rain at all fall, a soil, however retentive of moisture it be, must remain dry; and if rain were very frequently falling, the soil must be open indeed, if it be not constantly wet. The proportion of the different earths in a soil, therefore, must depend upon the quantity of rain which falls. In a rainy country, the soil ought to be open; in a dry country, it ought to be retentive of moisture. In the first, there ought to be a greater proportion of sand; in the second of clay.

Plants absorb food from the atmosphere;

2. That air is necessary for the vegetation of plants has been completely proven; and that a considerable portion at least of the carbonaceous matter which they contain is absorbed from the air, has been rendered probable by the late experiments of chemical philosophers. Three articles which furnish nourishment to plants are supplied by the atmosphere; namely, *carbonic acid*, *oxygen*, and *moisture*; but it has been disputed how far plants are capable of absorbing carbonic acid, without the assistance of the soil on which they usually vegetate.

Hassenfratz analysed the bulbous roots of hyacinths, in order to discover the quantity of water, carbon and hydrogen, which they contained; and by repeating the analysis on a number of bulbs, he discovered how much of these ingredients was contained in each weight of the bulb. He analysed also kidney beans and cress seeds in the same manner. Then he grew a number of each of these vegetables in pure water, taking the precaution to weigh them beforehand, in order to ascertain the precise quantity of carbon which they contained. The plants being then placed, some in doors, and others in the open air, grew and ripened, but produced no seed. He afterwards dried them, collecting with care all their leaves and every part which had dropt off during the course of the vegetation. On submitting each plant to a chemical analysis, he found that the quantity of carbon which it contained, was somewhat less than the quantity which was contained in the bulb or the seed from which the plant sprang\*.

These experiments have been lately repeated by Berthollet with a very different result. Sprigs of *mentha sylvestris*, allowed to vegetate for some time in distilled water, nearly doubled the portion of carbon which they originally contained†; but when the same experiment was repeated in a place where but little light had access, the carbon, instead of being increased, was somewhat diminished, as Hassenfratz had found. Hence it is probable, that the result obtained by Hassenfratz was

---

\* *Ann. de Chim.* xiii. 182.

† *Recherches Chimiques sur la Végétation*, p. 51.

## Book IV.

But this not  
sufficient.

owing to the want of light. Thus it cannot be doubted, that plants, even when they vegetate in pure water, are capable of absorbing nourishment from the air; but as plants in this situation cannot produce perfect seeds, and as they gradually decay and cease to vegetate, it is obvious that water and air alone are not sufficient.

3. The third, and only remaining source from which plants can draw their food, is the soil on which they grow. Now this soil consists of two parts; namely, *pure earths*, which constitute its basis, and the *remains* of animals and vegetables applied as manure.

One use of the earthy part of the soil is to furnish a support for the plants, and to administer the proper quantity of water to them; but as all plants contain earthy and saline matters, and as these substances are constantly present, we cannot avoid considering them as in some measure constituting an essential part of plants. Now there is reason to believe that the proportion of earthy and saline matters in plants is considerably influenced by the soil on which they vegetate. Sausure made beans grow in three different situations. The first set was supported by distilled water; the second was planted in sand and supported by rain water; the third set was planted in a pot filled with mould, and placed in a garden. The ashes yielded by these different plants were to each other in the following proportions\*.

Proportion  
of earth in  
plants varies  
with the  
soil.

1. Those fed by distilled water.. 3·9
2. Those fed by rain water..... 7·5
3. Those growing in soil..... 12·0

---

\* *Rochester*, p. 281.

quantity of fixed matter yielded by the beans vegetated in soil, was more than three times as much as what was obtained from those which had been washed solely by distilled water.

The philosopher examined the ashes of various plants growing on a granitic and on a calcareous soil\*. The plants which grew in the granitic soil contained a large proportion of silica and metallic oxides; those which grew in the calcareous, little or none of these, but a greater proportion of calcareous matter than the granitic plants. Thus the *pinus abies*, which grew on each of these soils, yielded the following quantities of fixed bodies:

	Granitic.	Calcar.
.....	3.60	.....15
the sulphates and muriates	4.24	.....63
rate of lime	46.34	.....0
rate of magnesia	6.77	.....0
.....	13.49	.....16
na	14.86	.....0
ic oxides	10.52	.....
	99.82	94+

These were composed of the following ingredients:

Granitic.	Calcareous.
silica	98.000 carbonate of lime
alumina	0.625 alumina
iron	0.625 oxide of iron
iron and manganese	0.025 petroleum
	99.275

g. viii. 185.—*Jour. de Phys.* lii. 27.—See the table of incinerated in Vol. V. p. 167. of this Work, where the result of all the experiments of this philosopher is given.



Book IV.

Whether  
plants gene-  
rate earth.

Thus it cannot be doubted, that the proportion of earthy matter contained in plants is considerably influenced by the nature of the soil on which they grow; but whether plants derive the whole of these fixed principles from the soil, or whether they are capable of forming them to a certain extent by the unknown powers of vegetation, are questions not yet finally decided. The experiments of Saussure would lead us to believe, that all the earths found in plants are absorbed from the soil; while those of Schrader seem to prove, that a portion of them is formed by vegetation, even when plants are so situated that they can derive no fixed principle from the soil on which they grow.

The Berlin Academy proposed as a prize question, *To determine the earthy constituents of the different kinds of corn, and to ascertain whether these earthy parts are formed by the process of vegetation.* The prize was gained by Schrader, an apothecary in Berlin, and the result of his experiments was published by the Academy in 1800. He analysed the seeds of *wheat, rye, barley, and oats*, and ascertained the portion of earth which each contains. He analysed in the same manner rye-straw\*. After having in this manner determined the proportion of earth which these seeds contained, he endeavoured to make them grow in some medium which could not furnish any earthy ingredient whatever. For a long time his attempts were baffled, every substance tried containing less or more of earth, and being therefore improper. At last he found that sulphur, in the state

Experi-  
ments of  
Schrader.

---

\* The result of these analyses have been given in page 165. of this Volume.

of flowers, might be used with success, as it contained no earthy matter whatever, and as the seeds grew in it, and sent out their roots perfectly well, when it was properly moistened with water. The oxides of antimony and zinc were the substances which answered best after sulphur. The seeds, then, were planted in sulphur, placed in a garden at a distance from all dust, put into a box to which the light and the air had free access, but from which all dust and rain were carefully excluded, and they were watered with distilled water. The corn raised in this manner was found by Schröder to contain *more* earthy matter than had existed in the seeds from which it had grown\*. Here, then, it would appear was the formation of earthy matter, unless we conceive that the air might have contained a sufficient quantity floating in it to furnish all that was found. Since the publication of his prize dissertation, Schröder has given to the public additional experiments on the same subject. In these he notices the trials of Saussure, and the results which were obtained from vegetables growing in calcareous and granitic soils; and particularly draws the attention of chemists to the fact ascertained by Saussure, that plants vegetating in a calcareous soil, which contained little or no silica, were yet found to yield a considerable portion of that earth†. Einhof likewise found in the ashes of a *pinus sylvestris*, which had grown in a soil that yielded no traces of lime, no less than 65 *per cent.* of that earth. He in-

---

\* Braconnot's experiments agree with those of Schröder, but they were not made with the same precautions. See *Ann. de Chim.* lxi. 187.

† Oehlen's *Jour.* iii. 538.

Book IV. forms us also, that he has frequently observed the *Helix prunastri* and *ciliaris* encrusted in the months of August and September with a coat of carbonate of lime, when no lime was to be found in the neighbourhood, and when other plants were not encrusted in that manner\*.

Saussure has observed very justly, that the absorption of earthy matter does not depend so much upon the earths which constitute the basis of the soil on which they grow, as upon the portion of earth held in solution in the liquid part of the soil. This observation will explain several of the facts above stated, but is by no means sufficient to set aside the experiments of Schrader, which go directly to prove that earths are formed by the processes of vegetation.

Soil contains salts,

Which act on plants.

4. Besides earths, plants always contain a portion of saline matter. Those that grow at a distance from the sea contain potash, while sea-plants contain soda and common salt. Phosphate of lime is a constant ingredient, and phosphate of potash a very common one. Some plants contain peculiar salts. Thus nitrate of soda is usually present in barley, nitrate of potash in nettles and the sun-flower, &c. It appears, from the experiments that have been made, that peculiar salts promote the vegetation of peculiar plants. Sea-plants require common salt, and languish in soils where it is not to be found. Borage, nettles, and pellitory, thrive only in soils which contain nitrate of lime or potash; gypsum promotes the vegetation of lucern and clover. Salts then are not inactive; and when properly ap-

---

\* Gahlen's *J. ur.* iii. 563.

† Saussure, *Recherches*, p. 264

plied, they promote the growth of vegetables. In these cases they appear to be absorbed by the plants which they invigorate. Duhamel found that sea-plants made little progress in soils which contain no common salt. Bullion made seeds of sun-flower to grow in a sandy soil containing no trace of nitre. On examining the plants, no nitrate of potash could be detected in them, but the salt made its appearance as usual when the plants were watered with a weak nitrous solution.

From the experiments of Saussure, we learn that plants absorb saline solutions in very different proportions, and that in general those are absorbed in greatest quantity which are most injurious to vegetation. He dissolved the following substances in water, in such proportions, that each solution contained  $\frac{1}{100}$ th part of its weight of the substance dissolved, except the last, which contained  $\frac{1}{10}$ th part.

Plants absorb different proportions of salts.

1. Muriate of potash
2. Muriate of soda
3. Nitrate of lime
4. Sulphate of soda effloresced
5. Muriate of ammonia
6. Acetate of lime
7. Sulphate of copper
8. Crystals of sugar
9. Gum arabic
10. Extract of soil

Into each of these solutions he put plants of *polygonum pericaria*, or of *bidens cannabina*, furnished with their roots.

The *polygonum* grew for five weeks in the solutions of muriate of potash, nitrate of lime, muriate of soda, sulphate of soda, and extract of soil; and the



Book IV.

roots increased in them as usual. It languished in the solution of sal-ammoniac, and the roots made no progress. It died in eight or ten days in the solutions of gum and of acetate of lime, and in less than three days in the solution of sulphate of copper.

When such a number of plants of *polygonum* were put into the solutions as to absorb one half of each in two days, the remaining half was found to have lost very different proportions of the salt which it had originally contained. Suppose the portion of salt originally in solution to be 100, the following Table exhibits the quantity of each which had disappeared when one half of the liquid was absorbed :

Muriate of potash	....14.7
Muriate of soda	.....13
Nitrate of lime	..... 4
Sulphate of soda	.....14.4
Muriate of ammonia	..12
Acetate of lime	..... 8
Sulphate of copper	...47
Sugar	.....29
Gum	..... 9
Extract of soil	..... 5

The *bidens* absorbed pretty much the same proportions, but in general did not vegetate so long as the *polygonum*. In these trials, it was the sulphate of copper and the sugar that were absorbed in greatest abundance, and these were the substances which proved most injurious to the plant. Saussure explains this apparent anomaly by supposing that a portion of the roots were soon destroyed in these liquids, and that then they absorbed the solution indiscriminately.

When various salts were dissolved at once in the

the solutions, and plants made to vegetate in them, it was found that different proportions of the salts were absorbed. The following Table exhibits the result of these trials, supposing, as before, the original weight of each salt to have been 100. Each solution contained  $\frac{1}{100}$ th part of its weight of each salt.

Solutions	Salts.	Salt absorbed.
1	Sulphate of soda effloresced	11.7
	Muriate of soda	22.0
2	Sulphate of soda effloresced	12
	Muriate of potash	17
3	Acetate of lime	8.1
	Muriate of potash	33
4	Nitrate of lime	4.5
	Muriate of ammonia	16.5
5	Acetate of lime	31
	Sulphate of copper	34
6	Nitrate of lime	17
	Sulphate of copper	34
7	Sulphate of soda	6
	Muriate of soda	10
	Acetate of lime	0
8	Gum	26
	Sugar	34

These experiments succeeded nearly equally with other plants, as the *mentha piperita* and the Scotch fir.

Book IV. When the roots were cut or removed, the plants absorbed all solutions indiscriminately. On examining the plants, the salts absorbed were found in them unaltered\*.

Thus it appears that plants do not absorb saline bodies indiscriminately. Saussure supposes that the difference depends rather upon the degree of liquidity which the solution possesses, than upon any discriminating power in the root. But if this were the case, it would be difficult to explain how so much greater a proportion of water should be absorbed than of the salt which it holds in solution.

Manure necessary for the growth of plants.

5. Water, then, carbonic acid, and oxygen, and perhaps also earths and salts, constitute a part of the food of plants; but it is very clear that the whole food is not furnished by these substances. It is well known, that if vegetables be successively raised on the same ground, they at last exhaust it, or render it sterile; and to prevent this, farmers are obliged to supply their grounds annually with a quantity of manure. Without this manure, or some equivalent, plants cannot be made to thrive, or to perfect their seeds. Neither water, air, nor earths, nor salts, will prevent them from perishing. Giobert mixed together the four earths, silica, alumina, lime, and magnesia, in the proper proportions to constitute a fertile soil; and after moistening them with water, planted several vegetables in them: but none of them grew well till he moistened his soil with water from a dunghil. Lampadius planted different vegetables in compartments of his garden, filled each

---

\* Saussure, *Recherches*, p. 247, 261.

with one of the pure earths, and watered them with the liquor which exuded from a dunghill. They all grew, notwithstanding the diversity of the soil; and each contained the usual earthy constituents of plants, notwithstanding the absence of these constituents from the soil.

It is not the earths which constitute a fertile soil, but the remains of animal and vegetable substances, and the proportion of these capable of being held in solution by water. It appears from the experiments of Mr Hassenfratz, that substances employed as manures produce effects in times proportioned to their degree of putrefaction; those substances which are most putrid producing the most speedy effects, and of course soonest losing their efficacy. Having manured two pieces of the same kind of soil, the one with a mixture of dung and straw highly putrefied, the other with the same mixture newly made, and the straw almost fresh, he observed, that during the first year, the plants which grew on the land manured with the putrefied dung produced a much better crop than the other: but the second year (no new dung being added), the ground which had been manured with the unputrefied dung produced the best crop; the same thing took place the third year; after which, both seemed to be equally exhausted\*. Here it is evident that the putrefied dung acted soonest, and was soonest exhausted. It follows from this, that carbon only acts as a manure when in a particular state of combination; and this state, whatever it may be, is evidently produced by putrefaction. Another experi-

---

\* *Ann. de Chim.* xiv. 57.



Book IV.

ment of the same chemist renders this truth still more evident. He allowed shavings of wood to remain for about ten months in a moist place till they began to putrefy, and then spread them over a piece of ground by way of manure. The first two years this piece of ground produced nothing more than others which had not been manured at all; the third year it was better, the fourth year it was still better, the fifth year it reached its maximum of fertility; after which it declined constantly till the ninth, when it was quite exhausted\*. Here the effect of the manure evidently depended upon its progress in putrefaction.

Vegetable  
manure.

When vegetables are allowed to putrefy in the open air, they are converted into a loose black substance, well known under the name of *vegetable mould*. On this mould plants grow with great vigour. It is the substance which renders newly cultivated lands in America, &c. so fertile. When exposed to the air, in the course of cultivation, it is gradually wasted and destroyed, and the lands are thus impoverished. This vegetable mould, therefore, is obviously one of the grand sources of the food of plants. It deserves, therefore, an accurate examination.

Its properties.

To Saussure and Einhof we are indebted for a chemical examination of its properties and constituents. Saussure employed in his experiments pure vegetable soil, which he procured either from the trunks of trees or from elevated rocks, where it was unmixed with any animal matter; and by passing it through a sieve, he removed from it the remains of undecayed vege-

---

\* *Ann. de Chim.* xiv. p. 58.

tables with which it was mixed \*. By distilling 200 grains (French) of mould from the oak, he obtained the following products; while the same quantity of undecayed oak yielded him the following proportions of the same constituents.

	Mould.	Oak.
Carbureted hydrogen gas . . . . .	124 inches (French)	116
Carbonic acid . . . . .	34 . . . . .	29
Water, containing pyrolignite of ammonia . . . . .	53 grains (French)	80
Empyreumatic oil . . . . .	10 . . . . .	13
Charcoal . . . . .	51 . . . . .	41½
Ashes . . . . .	8 . . . . .	0½

Nearly the same results were obtained by making similar experiments on other vegetables, and the mould which they yield when decayed. It appears from them, that the mould contains more charcoal, weight for weight, than the vegetables from which it proceeded. It yields also more ammonia, and therefore contains more azote.

Acids do not act powerfully on mould. Alcohol takes up a portion of extractive and resin. The fixed salts dissolve it almost completely, and ammonia is engaged during the solution. Acids throw down a small portion of a brown combustible powder. Water dissolves a portion of extractive; but the quantity is small, especially from the mould of fertile soils. 100 parts of water, left for five days on the mould, were found to have dissolved only 28 parts of it; and the same quantity, left on the soil of a

\* *Recherches sur la Végétation*, p. 162.

Book IV.

field which bore a fine crop of wheat, was found to have dissolved but four parts. It appears from the experiments of Saussure, that a mould which yielded to boiling water, by repeated decoctions,  $\frac{1}{17}$ th of its weight of extract, did not produce so good an effect upon beans as a mould which contained only half that quantity of soluble matter. But when mould is deprived of its soluble part by boiling water, though its appearance is not altered, yet it does not support plants nearly so well as mould which has not been thus exhausted\*.

The extract thus obtained from mould by Saussure did not deliquesce when exposed to the air. When distilled it yielded carbonate of ammonia. It produced no change on vegetable blues. When reduced to the consistence of a syrup it had a sweet taste; it precipitated by exposure to the air, and became turbid when mixed with lime-water, carbonate of potash, and most metallic solutions. Alcohol dissolves only a portion of it, and this part is very deliquescent†.

And constituents.

From the experiments of Einhof, it appears that the extract obtained from mould possesses very nearly the properties of the *extractive principal*. The mould which he employed in his experiments was from the soil of a wood, and had been formed by the leaves of the trees and the putrefied herbs. It was black, firm, produced no change on vegetable blues, and contained no undecayed plants‡. Water in which this mould was boiled was at first colourless; but by exposure to the

\* *Recherches*, p. 170.

† *Ibid.* p. 174.

‡ *Gehlen's Jour.* vi. 373.

acquired a brownish tint. The substance which in solution possessed exactly the characters of  
ative.

Chap. III.

periments upon vegetable mould have been made by Braconnot. He found no portion of it soluble in water. His other results resembled those of Saussure.

When an alkaline ley was boiled with mould it was dissolved. The residue had the exact appearance of pit coal \*.

Besides this fertile vegetable mould, Einhof has examined another of a different nature, to which he has

Acid vegetable mould.

given the name of *acid vegetable mould*. It occurs in wet meadows and marshes, and the plants which grow upon it in these situations are the different species of *juncus*, and *eriphorum*. It constitutes also the principal part of the mould in high-lying situations, such as moors where the soil is covered with heath (*erica*).

This mould is distinguished from the preceding by containing a notable portion of phosphoric and silicic acids, which give it the property of reddening vegetable blues. The extractive which it contains is nearly insoluble in water†.

This sour vegetable mould bears a considerable resemblance to peat, into which indeed it probably passes. Like it, peat contains a portion of phosphoric acid, and probably also silicic acid, and an extractive readily soluble in alcohol, though but sparingly in water‡.

Einhof has observed, that acid vegetable mould never occurs in those soils which abound in lime, and that

Effect of lime on mould.

\* *Ann. de Chim.* lxi. 191.

† *Gehlen*, vi. 379.

‡ *Gehlen's Jour.* iii. 400.



sists of an examination of the excrements of black cattle \*; and the second, by Berzelius, is upon the human excrementitious matter †. These add considerably to our knowledge of animal substances, and shall therefore be noticed in a subsequent part of this Work; but as they throw little light on the use of these matters as manures, it is unnecessary to give a detail in this place of the constituents of which they found them composed.

Such is the present state of our knowledge respecting the food of plants, as far as it is supplied by the soil in which they vegetate. It is probable that it is imbibed by the extremities of the roots only; for Duhamel observed, that the portion of the soil which is soonest exhausted is precisely that part in which the greatest number of the extremities of roots lies ‡. This shows us the reason why the roots of plants are continually increasing in length. By this means they are enabled, in some measure, to go in quest of nourishment. The extremities of the roots seem to have a peculiar structure adapted for the imbibing of moisture. If we cut off the extremity of a root, it never increases any more in length: therefore its use as a root has been in a great measure destroyed. But its sides send out fibres which act the part of roots, and imbibe food by their extremity. Nay, in some cases, when the extremity of a root is cut off, the whole decays, and a new one is formed in its place. This, as Dr Bell informs us, is the case with the hyacinth §.

The extremities of the roots contain no visible open-

Food absorbed by the ends of the roots.

It must be in a state of solution.

\* Gehlen's Jour. iii. 276.

† *Physique des Arbres*, ii. 239.

‡ Ibid. vi. 509.

§ *Manch. Mem.* ii. 412.

Book IV.

ing. Hence we may conclude that the food which they imbibe, whatever it may be, must be in a state of solution ; while the absolute necessity of water renders it probable that water is the solvent. And, in fact, the carbonaceous matter in all active manures is in such a state of combination that it is soluble in water. All the salts which we can suppose to make a part of the food of plants are more or less soluble in water. This is the case also with lime, whether it be pure or in the state of a salt ; magnesia and alumina may be rendered so by means of carbonic acid gas ; and Bergman, Macie, and Klaproth, have shown that even silica may be dissolved in water. We can see, therefore, in general, though we have no precise notions of the very combinations which are immediately imbibed by plants, that all the substances which form essential parts of that food *may* be dissolved in water.

---

### SECT. III.

#### OF THE MOTION OF THE SAP.

SINCE the food of plants is imbibed by their roots in a fluid state, it must exist in plants in a fluid state ; and unless it undergoes alterations in its composition just when imbibed, we may expect to find it in the plant unaltered. If there were any method of obtaining this fluid food from plants before it has been altered by them, we might analyse it, and obtain by that means a

much more accurate knowledge of the food of plants than we can by any other method. This plan indeed must fail, provided the food undergoes alteration just when it is absorbed by the roots: but if we consider, that when one species of tree is grafted upon another, each bears its own peculiar fruit, and produces its own peculiar substances, we can scarcely avoid thinking that the *great* changes at least, which the food undergoes after absorption, are produced, not in the roots, but in other parts of the plant.

If this conclusion be just, the food of plants, after being imbibed by the roots, must go directly to those organs where it is to receive new modifications, and to be rendered fit for being assimilated to the different parts of the plant. There ought therefore to be certain juices continually ascending from the roots of plants; and these juices, if we could get them pure and unmixed with the other juices or fluids which the plant must contain, and which have been secreted and formed from these primary juices, would be, very nearly at least, the food as it was imbibed by the plant. Now, during the vegetation of plants, there actually is a *juice* continually ascending from their roots. This juice has been called the *sap*, the *succus communis*, or the *lymph* of plants.

Sap of  
plants.

The sap is most abundant during the spring. At that season, if a cut be made through the bark and part of the wood of some trees, the sap flows out very profusely. The trees are then said to *bleed*. By this contrivance any quantity of sap we think proper may be collected. It is not probable, indeed, that by this method we obtain the ascending sap in all its purity; it is no doubt mixed with the peculiar juices of the plant:

Flows out  
in the  
spring.

**Book IV.** but the less progress vegetation has made, the purer we may expect to find it; both because the peculiar juices must be in much smaller quantity, and because its quantity may be supposed to be greater. We should therefore examine the sap as early in the season as possible, and at all events before the leaves have expanded.

Though a number of experiments, as we have seen in the last Chapter, have been made upon the sap, they are not of such a nature as to throw much light upon the food absorbed by plants. Chemistry has not made such progress as to enable even the most expert analysts to separate and distinguish small quantities of vegetable matter. It is even possible that the food, after it has been imbibed, may be, to a certain extent, modified and altered by the roots. In what manner this is done we cannot say, as we know very little about the vascular structure of the roots. We may conclude, however, that this modification is nearly the same in most plants: for one plant may be engrafted on another, and each continue to produce its own peculiar products; which could not be, unless the proper substances were conveyed to the digestive organs of all. There are several circumstances, however, which render the modifying power of the roots somewhat probable. It is even possible that the roots may, by some means or other, throw out again some part of the food which they have imbibed as excrementitious. This has been suspected by several physiologists; and there are several circumstances which render it probable. It is well known that some plants will not vegetate well after others; and that some again vegetate unusually well when planted in ground where certain plants had been



growing. These facts, without doubt, may be accounted for on other principles. If there be any excrementitious matter emitted by the roots, it is much more probable that this happens in the last stage of vegetation; that is to say, when the food, after digestion, is applied to the purposes which the root requires. But the fact ought to be supported by experiments, otherwise it cannot be admitted.

Mr Knight, to whose ingenious and important experiments and observations vegetable physiology lies under so many obligations, has rendered it extremely probable, that the sap, as it ascends, is mixed with a quantity of matter, previously deposited in the alburnum for that purpose, and ready prepared to be assimilated to the different vegetable organs\*. According to him, plants, after they have attained their full growth, are employed during the latter part of summer in preparing food for the expanding of the buds and blossoms in the succeeding spring. This food when prepared is deposited in the alburnum. Here it continues during the winter, and in next spring, mixing with the ascending sap, it affords nourishment to the buds and leaves. This ingenious opinion Mr Knight has supported by experiments and observations, sufficient, I think, to establish its truth. It constitutes a very important step in vegetable physiology, as it enables us to explain many circumstances in a satisfactory manner that appeared formerly altogether anomalous.

He ascertained, by experiments, that the sap increases

Mixed with  
true sap in  
its ascent.

---

\* On the State in which the True Sap of Trees is deposited during Winter. Phil. Trans. 1805.

Book IV. in density as it ascends towards the leaves. Sap extracted from the sycamore, close to the ground, was of the specific gravity 1·004; while that which flowed out at the height of seven feet was 1·008, and at the height of 12 feet 1·012. The sap of the birch was somewhat lighter, but its comparative increase of density, according to its height, was the same. When extracted near the ground, the sap, both of the sycamore and birch, was nearly tasteless; but it became sensibly sweet at some height, and the sweetness increased with the distance from the ground. Thus it appears, that the quantity of vegetable matter in sap increases as it flows towards the leaves; a direct proof that it imbibes and mixes with something during its passage. That this matter was lodged in the alburnum was rendered probable by comparing with each other the alburnum in winter and in summer. For if nutriment be laid up in the alburnum in winter, and employed in summer for the purposes of vegetation, it is obvious that the alburnum during winter ought to be denser, and ought to yield more extract to water, than the same substance in summer: both of which Mr Knight found to be the case. Oak poles, of the same age, and growing from the same stool, were felled, partly in December and partly in May. They were placed in the same situation, and dried for seven weeks by a fire. The specific gravity of the winter felled wood was 0·679, of the summer 0·609. When the alburnum alone was weighed, the specific gravity of the winter felled was 0·589; of the summer felled 0·533. 1000 grains of each being mixed with six ounces of boiling water, and left to macerate for 24 hours, the winter felled infusion was much deeper coloured than the other. Its specific gravity

was 1'002; while that of the summer felled infusion was 1'001. This deposition of nutritious matter explains why the alburnum of trees felled in winter is much more solid and valuable than the alburnum of trees felled in summer.

The sap, as Dr Hales has shown us, ascends with a very considerable force. It issued during the bleeding season with such impetuosity from the cut end of a vine branch, that it supported a column of mercury 32 $\frac{1}{2}$  inches high\*.

Now, what is the particular channel through which the sap ascends, and what is the cause of the force with which it moves? These are questions which have excited a great deal of the attention of those philosophers who have made the physiology of vegetables their particular study; but the examination of them is attended with so many difficulties that they are very far from being decided.

It is certain that the sap flows from the roots towards the summit of the tree. For if in the bleeding season a number of openings be made in the tree, the sap begins first to flow from the lowest opening, then from the lowest but one, and so on successively, till at last it makes its appearance at the highest of all; and when Duhamel and Bonnet made plants vegetate in coloured liquors, the colouring matter, which was deposited in the wood, appeared first in the lowest part of the tree, and gradually ascended higher and higher, till at last it reached the top of the tree, and tinged the very leaves.

Sap ascends.

\* *Veg. Stat.* i. 105.

Book IV.  
Through  
the wood.

It seems certain too that the sap ascends through the wood, and not through the bark of the tree: for a plant continues to grow even when stript of a great part of its bark; which could not happen if the sap ascended through the bark. When an incision, deep enough to penetrate the bark, and even part of the wood, is carried quite round a branch, provided the wound be covered up from the external air, the branch continues to vegetate as if nothing had happened; which could not be the case if the sap ascended between the bark and the wood. It is well known, too, that in the bleeding season little or no sap can be got from a tree unless our incision penetrate deeper than the bark.

These conclusions have been confirmed by the experiments made lately by Coulomb and Knight. Coulomb observed that no sap ever flows from the poplar till the tree be cut nearly to the centre\*. Mr Knight observed that coloured infusions always pass through the alburnum, and that whenever the alburnum is cut through the plant dies†.

In peculiar  
vessels.

As the sap is never found in the parenchyma, it must of necessity be confined in particular vessels; for if it were not, it would undoubtedly make its appearance there. Now, what are the vessels through which the sap ascends?

Grew and Malpighi, the first philosophers who examined the structure of plants, took it for granted that the woody fibres were tubes, and that the sap ascended through them. For this reason they gave these fibres the name of *lymphatic vessels*. But they were unable,

\* *Jour. de Phys.* xlix. 392

† *Phil. Trans.* 1801. p. 116.



assisted by the best microscopes, to detect in these fibres which had the appearance of a d succeeding observers have been equally un-  
 The conjecture therefore of Malpighi and out the nature and use of these fibres, remains supported by any proof. Duhamel has even to overturn it altogether: for he found that dy fibres are divisible into smaller fibres, and in into still smaller; and even, by the assist-  
 the best microscopes, he could find no end of vision\*. Now, granting these fibres to be is scarcely possible, after this, to suppose ap really moves through tubes, whose diame-  
 most infinitely small. There are, however, plants which may easily be distinguished by of a small microscope, and even in many cases ked eye. These were seen, and distinctly de-  
 y Grew and Malpighi. They consist of a ted round like a corkscrew. If we take a inder of wood, and wrap round it a slender  
 , so closely that all the rings of the wire touch , and if, after this, we pull out the wooden altogether, the brass wire thus twisted will  
 very good representation of these vessels. If old of the two ends of the brass wire thus nd pull them, we can easily draw out the wire  
 derable length. In the same manner, when old of the two extremities of these vessels, we them out to a great length. Malpighi and ding them always empty, concluded that they

---

\* *Physique des Arbres*, i. 57.

Book IV.

were intended for the circulation of the air through the plant, and therefore gave them the name of *tracheæ*; which word is used to denote the *windpipe* of animals. These *tracheæ* are not found in the bark; but Hedwig has shown that they are much more numerous in the wood than was supposed; and that they are of very different diameters; and Reichel has demonstrated that they go to the minutest branches, and spread through every leaf. He has shown, too, that they contain sap; and Hedwig has proved that the notion which generally prevailed of their containing nothing but air, arose from this circumstance, that the larger *tracheæ*, which alone were attended to, lose their sap as soon as they are cut; and of course, unless they are inspected the instant they are divided, they appear empty\*. Is it not probable, then, from the discoveries of that very ingenious physiologist, that the *tracheæ* are, in reality, the sap vessels of plants? Indeed it seems established, by the experiments both of Reichel and Hedwig, that almost all the vessels of plants may, if we attend only to their structure, be denominated *tracheæ*. But whether the structure of the sap vessels be similar to that of the *tracheæ* or not, it has been perfectly ascertained that the sap ascends in vessels, and that these vessels are situated in the wood, chiefly indeed in the *alburnum*. Hence Mr Knight has given them the name of *alburnous* vessels.

Its ascen-  
sion

But by what powers is the sap made to ascend in these vessels? and not only to ascend, but to move with very considerable force; a force, as Hales has shown,

---

\* *Fundament. Hist. Nat. Muscor. Frondes.* Part L. p. 54.

to overcome the pressure of 43 feet perpendicular water \*?

Chap. III.

ascribed this phenomenon to the levity of the rich, according to him, entered the plant in the very light vapour. But this opinion will not stand the slightest examination. Malpighi supposed sap was made to ascend by the contraction and of the air contained in the air vessels. But were we to grant that the tracheæ are air vessels, according to this hypothesis, could only ascend when a change of temperature takes place; which is not the fact. And even if we were to waive every objection of that kind, the hypothesis would not account for the circulation of the sap, unless the sap vessels were provided with valves. Now the experiments of Duhamel show that no valves can possibly exist in them: For branches imbibe moisture nearly equally by either end; and consequently the sap moves with equal facility both upwards and downwards, which would not do were there valves in the vessels. Besides, it is known, from many experiments, that we can invert the roots of a tree into the branches, and the branches into the roots, by covering the branches with earth, and exposing the roots to the air †. Now it would be impossible if the sap vessels were provided with valves. The same remarks overturn the hy-

Ascribed to its levity;

To the contraction of air;

\* Stat. i. 107.

† Duhamel has lately shown that the inverted shoots by no means wither, but grow as well as when in their natural position; and has even made it appear that the vessels of the bark are furnished with valves, or with something equivalent. But no evidence has been adduced to induce us to believe that this is the case with the sap vessels.—See his *Observations on the Sap of Trees*. *Phil. Trans.* 1804.

Book IV.

pothesis of Mr de la Hire, which is merely that of Malpighi, expressed with greater precision, and with a greater parade of mechanical knowledge. Like Borelli, he placed the ascending power of the sap in the parenchyma. But his very experiments, had he attended to them with care, would have been sufficient to show the imperfection of his theory.

The greater number of philosophers (for it is needless to mention those who, like Perrault, had recourse to fermentation, nor those who introduced the weight of the atmosphere) have ascribed the motion of the sap to *capillary attraction*.

To capillary attraction,

There exists an attraction between many solid bodies and liquids; in consequence of which, if these solid bodies be formed into small tubes, the liquid enters them, and rises in them to a certain height. But this is perceptible only when the diameter of the tube is very small. Hence the attraction has been denominated *capillary*. We know that there is such an attraction between vegetable fibres and watery liquids; for such liquids will ascend through dead vegetable matter. It is highly probable, therefore, that the food of plants enters the roots, in consequence of the capillary attraction which subsists between the sap vessels and the liquid imbibed. This species of attraction, then, will account perfectly well for the entrance of moisture into the mouths of the sap vessels: But will it account also, as some have supposed, for the ascent of the sap, and for the great force with which it ascends?

The nature and laws of *capillary attraction* have been very much overlooked by: enough concerning it to en question. It consists in:



the particles of the liquid and of the tube. It has been demonstrated, that it does not extend, or at least that it produces no sensible effect, at greater distances than  $\frac{1}{1000}$ th part of an inch. It has been demonstrated, that the water ascends, not by the capillary attraction of the whole tube, but of a slender film of it; and Clairant has shown that this film is situated at the lowermost extremity of the tube\*. This film attracts the liquid with a certain force; and if this force be greater than the cohesion between the particles of the liquid, part enters the tube, and continues to enter, till the quantity above the attracting film of the tube just equals, by its weight, the excess of the capillary attraction between the tube and the liquid above the cohesion of the liquid. The quantity of water, therefore, in the tube is pretty nearly the measure of this excess; for the attracting film is probably very minute.

Chap. III.

It has been demonstrated, that the heights to which liquids rise in capillary tubes, are inversely as the diameter of the tube. Consequently the smaller the diameter of the tube, the greater is the height to which the liquid will rise. But the particles of water are not infinitely small; therefore, whenever the diameter of the tube is diminished beyond a certain size, water cannot ascend in it, because its particles are now larger than the bore of the tube. Consequently the rise of water

But without reason.

---

\* The action of all the other films, of which the tube is composed, on the water, as far as it is measured by its effect, is nothing at all. For a particle of water in the tube (except those attracted by the under-  
 film) is attracted upwards and downwards by the same number of  
 is therefore precisely in the same state as if it were not attracted

Book IV.

in capillary tubes must have a limit: if they exceed a certain length, how small soever their bore may be, water will either not rise to the top of them, or it will not enter them at all. We have no method of ascertaining the precise height to which water would rise in a capillary tube, whose bore is just large enough to admit a single particle of water. Therefore we do not know the limit of the height to which water may be raised by capillary attraction. But whenever the bore is diminished beyond a certain size, the quantity of water which rises in it is too small to be sensible. We can easily ascertain the height which water cannot exceed in capillary tubes before this happens; and if any person calculate, he will find that this height is not nearly equal to the length of the sap vessels of many plants. But besides all this, we see in many plants very long sap vessels, of a diameter too large for a liquid to rise in them a single foot by capillary attraction, and yet the sap rises in them to very great heights.

If any person says that the sap vessels of plants gradually diminish in diameter as they ascend; and that, in consequence of this contrivance, they act precisely as an indefinite number of capillary tubes, one standing upon another, the inferior serving as a reservoir for the superior—I answer, that the sap may ascend by that means to a considerable height: but certainly not in any greater quantity than if the whole sap vessel had been precisely of the bore of its upper extremity; for the quantity of sap raised must depend upon the bore of the upper extremity, because it must all pass through that extremity.

But farther, if the sap rises only in the vessels of plants by capillary attraction, it should be so far from

flowing out at the extremity of a branch, with a force sufficient to overcome the pressure of a column of water 43 feet high, that it could not flow out at all. It would be impossible in that case for any such thing as the bleeding of trees ever to happen.

If we take a capillary tube, of such a bore that a liquid will rise in it six inches, and after the liquid has risen to its greatest height, break it short three inches from the bottom, none of the liquid in the under half flows over. The tube, thus shortened, continues indeed full, but not a single particle of liquid ever escapes from it. And how is it possible for it to escape? The film, at the *upper* extremity of the tube, must certainly have as strong an attraction for the liquid as the film at the *lower* extremity. As part of the liquid is within its attracting distance, and as there is no part of the tube above to counterbalance this attraction, it must of necessity attract the liquid nearest it, and with a force sufficient to counterbalance the attraction of the undermost film, how great soever we may suppose it. Of course no liquid can be forced up, and consequently none can flow out of the tube. Since, then, the sap *flows out* at the upper extremity of the sap vessels of plants, we are absolutely certain that it does not ascend in them merely by its capillary attraction, but that there is some other cause.

It is impossible, therefore, to account for the motion of the sap in plants by any mechanical or chemical principles whatever; and he who ascribes it to these principles has not formed to himself any clear or accurate conception of the subject. We know indeed that heat is an agent; for Dr Walker found that the ascent of the sap is much promoted by heat, and that after it



Book IV.

had begun to flow from several incisions, cold made it give over flowing from the higher orifices while it continued to flow at the lower \*. But this cannot be owing to the dilating power of heat; for unless the sap vessels of plants were furnished with valves, dilatation would rather retard than promote the ascent of the sap.

The vessels  
must con-  
tract.

We must, therefore, ascribe it to some other cause: the vessels themselves must certainly act. Many philosophers have seen the necessity of this, and have accordingly ascribed the ascent of the sap to *irritability*. But the first person who gave a precise view of the manner in which the vessels probably act was Saussure. He supposes that the sap enters the open mouths of the vessels at the extremity of the roots; that these mouths then contract, and by that contraction propel the sap upwards; that this contraction gradually follows the sap, pushing it up from the extremity of the root to the summit of the plant. In the mean time the mouths are receiving new sap, which in the same manner is pushed upwards †. Whether we suppose the contraction to take place precisely in this manner or not, we can scarcely deny that it must take place; but by what means it is impossible at present to say. The agent cannot precisely resemble the muscles of animals; because the whole tube, however cut or maimed, still retains its contracting power, and because the contraction is performed with equal readiness in every direction ‡.

\* Edin. Trans. i.

† Mr Knight thinks it probable that the contraction and expansion of what

Agel. Meth. Phys. Veget. p. 267.

the sap is propelled by the contraction

of the vessels, or by other gradual



It is evident, however, that they must be the same in kind. Perhaps the particular structure of the vessels may fit them for their office. Does ring after ring contract its diameter? The contracting agents, whatever they are, seem to be excited to act by some stimulus communicated to them by the sap. This capacity of being excited to action is known in physiology by the name of *irritability*; and there are not wanting proofs that plants are possessed of it. It is well known that different parts of plants move when certain substances act upon them. Thus the flowers of many plants open at sunrise, and close again at night. Linnæus has given us a list of these plants. Des Fontaines has shown that the stamina and antheræ of many plants exhibit distinct motions \*. Dr Smith has observed, that the stamina of the barberries are thrown into motions when touched †. Roth has ascertained that the leaves of the *drosera longifolia* and *rotundifolia* have the same property. Mr Coulomb, too, who has adopted the opinion that the motion of the sap in plants is produced by the contraction of vessels, has even made a number of experiments in order to show this contraction. But the fact is, that every one has it in his power to make a decisive experiment. Simply cutting a plant, the *euphorbia peplis* for instance, in two places, so as to separate a portion

---

the wood, between the laminæ of which the vessels run. (*Phil. Trans.* 1801, p. 344.) By *silver grain* is meant those thin longitudinal fibres, diverging in every direction from the pith, and composed of the lymphatic vessels of Grew and Malpighi. I do not see how the contraction of these laminæ could propel the sap through the sap vessel, destitute as they are of valves, unless it were a contraction precisely similar to what Saussure supposed to take place in the sap vessels.

• *Mém. Par.* 1787.

† *Phil. Trans.* lxxviii.

Book IV.

of the stem from the rest, is a complete demonstration that the vessels actually do contract. For whoever makes the experiment, will find that the milky juice of that plant flows out at both ends so completely, that if afterwards we cut the portion of the stem in the middle no juice whatever appears. Now it is impossible that these phenomena could take place without a contraction of the vessels; for the vessels in that part of the stem which has been detached cannot have been more than full; and their diameter is so small, that if it were to continue unaltered, the capillary attraction would be more than sufficient to retain their contents, and consequently not a drop would flow out. Since, therefore, the whole liquid escapes, it must be driven out forcibly, and consequently the vessels must contract.

It seems pretty plain, too, that the vessels are excited to contract by various stimuli; the experiments of Coulomb and Saussure render this probable, and an observation of Dr Smith Barton makes it next to certain. He found that plants growing in water vegetated with much greater vigour, provided a little camphor was thrown into the water\*.

---

\* *Ann. de Chim.* xxiii. 63.

## SECT. IV.

## OF THE FUNCTIONS OF THE LEAVES.

It has been ascertained that the sap ascends to the leaves, that it there undergoes certain alterations, and is converted into another fluid called the *succus proprius*, or *true sap*; which, like the blood in animals, is afterwards employed in forming the various parts found in plants. Now, the changes which it undergoes in the leaves, provided we can trace them, must throw a great deal of light upon the nature of vegetation. These changes are produced in part during the day, in part during the night. Now, as the changes of the leaves during the day are very different from what they are during the night, it will be proper to consider them separately.

Peculiar  
juice form-  
ed by the  
leaves.

As soon as the sap arrives at the leaves, than a part of it is thrown off by evaporation.

Part of the  
sap trans-  
pires.

The quantity thus perspired bears a very great proportion to the moisture imbibed. Mr Woodward found that a sprig of mint, weighing 27 grains, in 77 hours imbibed 2558 grains of water, and yet its weight only increased 15 grains; therefore it must have lost 2543 grains. The same experiment was repeated by this philosopher on other plants; the following exhibits the result\*:

Its quanti-  
ty.

\* *Phil. Trans.* 1699. xxix, 193.

Book IV.

Plants and Water.	Weight.		Gain in 77 days.	Water wanted.
	When put in	When taken out.		
	gr.	gr.	gr.	gr.
Spearmint in spring water	27	42	15	2558
Spearmint in rain water	28 $\frac{1}{2}$	45 $\frac{1}{2}$	17 $\frac{1}{2}$	3004
Spearmint in Thames water	28	54	26	2493
Common nightshade in spring water	49	106	57	3708
Lathyrus in spring water	98	101 $\frac{1}{2}$	3 $\frac{1}{2}$	2501

These experiments demonstrate the great quantity of matter which is constantly leaving the plant. Dr Hales found that a cabbage transmitted daily a quantity of moisture equal to about half its weight; and that a sun-flower, three feet high, transmitted in a day 1 lb. 14 oz. avoirdupois †. He showed, that the quantity of transpiration in the same plant was proportional to the surface of the leaves, and that when the leaves were taken off the transpiration nearly ceased ‡. By these observations, he demonstrated that the leaves are the organs of transpiration. He found, too, that the transpiration was nearly confined to the day, very little taking place during the night §; that it was much promoted by heat, and stopped by rain and frost \*: and Millar ||, Guettard ¶, and Sennebier, have shown that the transpiration is also very much promoted by sunshine.

The quantity of moisture imbibed by plants depends

† *Veget. Stat.* i. 5. and 15.‡ *Ibid.* p. 30.§ *Ibid.* p. 5.\* *Ibid.* p. 27. and 48.|| *Ibid.* p. 22.¶ *Mem. Par.* 1748.



very much upon what they transpire: The reason is evident: when the vessels are once filled with sap, if none be carried off, no more can enter; and, of course, the quantity which enters must depend upon the quantity emitted.

Chap. III.

2. In order to discover the nature of the transpired matter, Hales placed plants in large glass vessels, and by that means collected a quantity of it<sup>\*</sup>. He found that it resembled pure water in every particular, excepting only that it sometimes had the odour of the plant. He remarked, too, as Guettard and Duhamel did after him, that when kept for some time it putrefied, or at least acquired a stinking smell. Sennebier subjected a quantity of this liquid to a chemical analysis.

Nature of  
the perspi-  
red matter.

He collected 13090 grains of it from a vine during the months of May and June. After filtration he gradually evaporated the whole to dryness. There remained behind two grains of residuum. These two grains consisted of nearly  $\frac{1}{2}$  grain of carbonate of lime,  $\frac{1}{12}$  grain of sulphate of lime,  $\frac{1}{3}$  grain of matter soluble in water, and having the appearance of gum, and  $\frac{1}{4}$  grain of matter which was soluble in alcohol, and apparently resinous. He analysed 60768 grains of the same liquid, collected from the vine during the months of July and August. On evaporation he obtained  $2\frac{1}{2}$  grains of residuum, composed of  $\frac{1}{2}$  grains of carbonate of lime,  $\frac{1}{2}$  grain of sulphate of lime,  $\frac{1}{4}$  grain of mucilage, and  $\frac{1}{4}$  grain of resin. The liquid transpired by the *aster Novæ Angliæ* afforded precisely the same ingredients†.

\* *Veget. Stat.* i. 49.

† *Encyc. Meth. Phys. Veget.* 287.

Book IV.  
Proportion  
to the li-  
quid ab-  
sorbed.

3. Sennebier attempted to ascertain the proportion which the liquid transpired bore to the quantity of moisture imbibed by the plant. But it is easy to see that such experiments are liable to too great uncertainties to be depended on. His method was as follows: He plunged the thick end of the branch on which he made the experiment into a bottle of water, while the other end, containing all its leaves, was thrust into a very large glass globe. The apparatus was then exposed to the sunshine. The quantity imbibed was known exactly by the water which disappeared from the bottle, and the quantity transpired was judged of by the liquid which condensed and trickled down the sides of the glass globe. The following Table exhibits the result of his experiments:

Plants.	Imbibed.	Perspired.	Time
Peach.....	100 gr.....	35 gr	
Ditto .....	210.....	90	
Ditto .....	220.....	120	
Mint .....	200.....	90.....	2 days.
Ditto .....	575.....	120.....	10
Rasp .....	725.....	560.....	2
Ditto .....	1232.....	765.....	2
Peach.....	710.....	295.....	1
Apricot .....	210.....	180.....	1

In some of his experiments no liquid at all was condensed. Hence it is evident that the quantity of matter transpired cannot be deduced from these experiments. The mouth of the glass globe does not seem to have been accurately closed; the air within it communicated with the external air; consequently the quanti-

ly condensed must have depended entirely upon the state of the external air, the heat, &c. Chap. III.

4. The first great change, then, which takes place upon the sap after it arrives at the leaves, is the evaporation of a great part of it; consequently what remains must be very different in its proportions from the sap. The leaves seem to have particular organs adapted for throwing off part of the sap by transpiration; for the experiments of Guettard <sup>u</sup>, Duhamel <sup>†</sup>, and Bonnet <sup>‡</sup>, show that it is performed chiefly by the upper surfaces of leaves, and may be nearly stopped altogether by varnishing that surface. Peculiar organ of transpiration.

The leaves of plants become gradually less and less fit for this transpiration; for Sennebier found that when all other things are equal, the transpiration is much greater in May than in September <sup>§</sup>. Hence the reason that the leaves are renewed annually. Their organs become gradually unfit for performing their functions, and therefore it is necessary to renew them. Those trees which retain their leaves during the winter, were found by Hales and succeeding physiologists to transpire less than others. It is now well known that these trees also renew their leaves. Why the leaves fall off.

II. Leaves have also the property of absorbing carbonic acid gas from the atmosphere. Leaves absorb carbonic acid.

We are indebted for this very important discovery to the experiments of Dr Priestley. It has been long known that when a candle has been allowed to burn out a quantity of air, no candle can afterwards be made

<sup>u</sup> *Par.* 1749.

*de des Feuilles*, 1. *Mem.*

<sup>†</sup> *Physique des Arbres*, i. 158.

<sup>‡</sup> *Encyc. Meth. Veget.* 285.

Book IV.

to burn in it. In the year 1771, Dr Priestley made a sprig of mint vegetate for ten days in contact with a quantity of such air : after which he found that a candle would burn in it perfectly well \*. This experiment he repeated frequently, and found that it was always attended with the same result. According to the opinion at that time universally received, that the burning of candles rendered air impure by communicating phlogiston to it, he concluded from it, that plants, while they vegetate, absorb phlogiston.

Carbonic acid gas was at that time supposed to contain phlogiston. It was natural, therefore, to suppose that it would afford nourishment to plants, since they had the property of absorbing phlogiston from the atmosphere. Dr Percival had published a set of experiments ; by which he endeavoured to show that this was actually the case.

These experiments induced Dr Priestley, in 1776, to consider the subject with more attention. But as, in all the experiments which he made, the plants confined in carbonic acid gas very soon died, he concluded that carbonic acid gas was not a food, but a poison to plants †. Mr Henry of Manchester was led in 1784, probably by the contrariety of these results, to examine the subject. His experiments, which were published in the Manchester Transactions ‡, perfectly coincided with those of Dr Percival. For he found that carbonic acid gas, so far from killing plants, constantly promoted their growth and vigour. Meanwhile Mr Sennebier was occupied at Geneva with the same subject;

\* *On Air*, iii. 251.† *Ibid*, i. 100.‡ *Vol*, ii. 341.



published the result of his researches in his *Physico-Chymiques* about the year 1780. His experiments showed, in the clearest manner, that acid gas is used by plants as food. The thing was supported by Ingenhousz in his second

The experiments of Saussure junior, published 1797, have at last put the subject beyond the dispute. From a careful comparison of the experiments of those philosophers, it will not be difficult to discover the various phenomena, and to reconcile the seeming contradictions which occur in them, as are as follows :

Plants will not vegetate in an atmosphere of pure acid, nor if their atmosphere contains  $\frac{1}{2}$ ths of its that gas. They vegetate in the sun when confined in atmospheres containing  $\frac{1}{4}$ ,  $\frac{1}{8}$ th, or  $\frac{1}{16}$ th, of that gas, vegetation improves as the quantity of gas diminishes. When the atmosphere contains only  $\frac{1}{16}$ th of carbonic acid gas, plants grow in it considerably in the sun, than when placed in an atmosphere of pure air ; but when plants are placed in the sun in the presence of carbonic acid always injures vegetation instead of promoting it\*.

Saussure has shown, that plants will not vegetate in the sun when totally deprived of carbonic acid. They vegetate indeed well enough in air which has been previously deprived of carbonic acid gas ; but when a quantity of lime was put into the glass vessel containing them, they no longer continued to

---

Saussure, *Recherches Chimiques sur la Végétation*, p. 30.

Book IV.

grow, and the leaves in a few days fell off\*. The air, when examined, was found to contain no carbonic acid gas. The reason of this phenomenon is, that plants (as we shall see afterwards) have the power of forming and giving out carbonic acid in certain circumstances; and this quantity is sufficient to continue their vegetation for a certain time. But if this new formed gas be also withdrawn, by quicklime for instance, which absorbs it the instant it appears, the leaves droop, and refuse to perform their functions†. Carbonic acid gas, then, applied to the leaves of plants, is *essential* to vegetation.

4. The direct contrary takes place in the shade. Plants not only continue to vegetate when deprived of all carbonic acid by means of lime; but they flourish more than if it were allowed to remain‡.

Emit oxygen gas.

5. Dr Priestley, to whom we are indebted for many of the most important facts relative to vegetation, observed, in the year 1778, that plants, in certain circumstances, emitted oxygen gas§; and Ingenhousz very soon after discovered that this gas is emitted by the leaves of plants, and only when they are exposed to the bright light of day. His method was to plunge the leaves of different plants into vessels full of water, and then expose them to the sun, as Bonnet, who had observed the same phenomenon, though he had given a wrong explanation of it, had done before him. Bub-

---

\* *Ann. de Chim.* xxiv. 145. 148.

† Braconnot has rendered it probable, that in this experiment it was not the absence of carbonic acid, but the deleterious effects of the lime that killed the plants in Saussure's experiments. *Ann. de Chim.* lxi. 187.

‡ Saussure, *Recherches*, p. 36.

§ *On Air*, iii. 284.

bles of oxygen gas very soon detached themselves from the leaves, and were collected in an inverted glass vessel \*. He observed, too, that it was not a matter of indifference what kind of water was used. If the water, for instance, had been previously boiled, little or no oxygen gas escaped from the leaves; river water afforded but little gas; but pump water was the most productive of all †.

Sennebier proved, that if the water be previously deprived of all its air by boiling, the leaves do not emit a particle of air; that those kinds of water which yield most air, contain in them the greatest quantity of carbonic acid gas; that leaves do not yield any oxygen when plunged in water totally destitute of carbonic acid gas; that they emit it abundantly when the water, rendered unproductive by boiling, is impregnated with carbonic acid gas; that the quantity of oxygen emitted, and even its purity, is proportional to the quantity of carbonic acid gas which the water contains; that water impregnated with carbonic acid gas gradually loses the property of affording oxygen gas with leaves; and that whenever this happens, all the carbonic acid gas has disappeared; and on adding more carbonic acid gas the property is renewed ‡. These experiments prove, in a most satisfactory manner, that the oxygen gas which the leaves of plants emit depends upon the presence of carbonic acid gas; that the leaves absorb carbonic acid gas, decompose it, give out the oxygen, and retain the carbon. They have been lately confirmed by the expe-

By decomposing carbonic acid.

\* Ingenhousz on *Veget.* i. 15, &c.

† *Ibid.* 33.

‡ *Essays Method. Physiol. Veget.* 131.

Book IV.

The decomposition performed by the parenchyma.

periments of Dr Woodhouse. To this gentleman likewise we are indebted for a very full set of experiments on the quantity of gas produced by exposing different plants in water to sunshine for given times \*.

6. Sennebier has ascertained, that the decomposition of the carbonic acid takes place in the parenchyma. He found that the epidermis of a leaf would, when separated, give out no air, neither would the nerves in the same circumstances; but upon trying the parenchyma, thus separated from its epidermis and part of its nerves, it continued to give out oxygen as before †.

That the decomposition is performed by peculiar organs, is evident from an experiment of Ingenhousz. Leaves cut into small pieces continued to give out oxygen as before; but leaves pounded in a mortar lost the property entirely. In the first state, the peculiar structure remained; in the other, it was destroyed. Certain experiments of Count Rumford, indeed, may seem incompatible with this conclusion; and they will naturally occur to the reader as an objection. He found that dried leaves, black poplar, fibres of raw silk, and even glass, when plunged into water, gave out oxygen gas by the light of the sun; but when Sennebier repeated these experiments, they did not succeed ‡. It was probably the air contained in the water which separated in the Count's experiments §.

\* See Nicholson's *Jour.* ii. 154. and *Ann. de Chim.* xiii. 200.

† *Encyc. Method. Physiol. Veget.* 180. ‡ *Ann. de Chim.* i. 115.

§ Dr Woodhouse tried the experiments with filaments of asbestos, baked horse hair, cotton, panicles of *rhus coriaria*, cotton of *asclepias syriaca*, hairy plumes of *clematis crispa*, spikes of *panicum glaucum*, char-



From the experiments of Saussure, we learn that the quantity of carbonic acid thus absorbed and decomposed varies greatly in different plants, even when in the same circumstances. The *lythrum salicaria* was found to absorb seven or eight times its bulk of gas in a day; while the *cactus opuntia*, and fleshy-leaved plants, did not absorb above a fifth quantity. The portion absorbed, according to Saussure, depends upon the surface of the plant; and the thin leaved plants must absorb more than those that have fleshy leaves\*.

Chap. III.

Carbonic acid absorbed varies in different plants.

It does not appear that the whole of the oxygen absorbed in the carbonic acid absorbed is emitted again by the plant. A considerable portion of it seems to be retained.

The whole oxygen not emitted.

This, at least, is the result which follows from a set of experiments made by Saussure to ascertain the point. He mixed carbonic acid with common air, in such a proportion that it occupied one-fifth of the mass. Jars, standing over mercury (covered with a thin film of water), were filled with this mixture; and plants of *vinca minor*, growing in a vessel filled with water, were introduced into the jars. These plants, thus placed, were exposed for six or seven days to the sun, from five in the morning to five in the evening, while the temperature of the air was 70°; during which time they vegetated with great vigour. At the end of the experiment, the bulk of the air in the jar was not sensibly altered. No carbonic acid could be detected in it. The pro-

---

\* Saussure; each of these, he affirms, yielded in water a little oxygen more pure than the leaves of plants. Nicholson's *Jour.* ii. 158.  
*Tratado Chimique*, p. 56.

Book IV.

portion of oxygen was  $24\frac{1}{2}$  per cent. The following Table exhibits the proportion of the constituents of air, in French cubic inches, when put into the jar, after the plants had vegetated in it six days\* :

	When put in.	When taken out.
Azote	211.02	218.95
Oxygen	56.33	71.05
Carbonic acid	21.75	0.00
	290.00	290.00

Some azote  
emitted.

Thus the whole 21.75 inches of carbonic acid was absorbed ; but the oxygen emitted was only 14 inches, whereas the whole oxygen in the carbonic acid would have amounted to 21.75 inches. The difference, amounting to about seven inches, was made by a quantity of azote, which had been given out by the plants along with the oxygen. The following Table exhibits the result of similar experiments, made by this philosopher, on other plants. All the numbers denote cubic inches.

---

\* *Recherches*, p. 40.

# FUNCTIONS OF THE LEAVES.

350

Chap. III.

Plants.	Bulk of plants.	Air in jar.	Carbonic acid, per cent. in ditto.	Duration of experiment. Days.	Carbonic acid per cent. in residuary air.	Oxygen per cent. in do.	Carbonic acid absorb. ed.	Gas emitted.		Diminution of bulk of residuary gas.
								Oxygen.	Azote.	
<i>Mentha aquatica</i>	0.5	328	7.5	10	2.5	23.5	15.6	11.26	4.34	0
<i>Lythrum salicaria</i>	0.14	25	10	7	0	27.25	7.5	6.13	1.1	0.5
<i>Pinus Genevensis</i>	0.5	280	7	18	1.5	24.5	15.5	12.5	1	2
<i>Cactus opuntia</i>	1.1	155	10	8	4	34	9.3	6.4	2.9	0

us it appears that plants, when exposed to the carbolic acid, decompose it, and throw the greatest part of the oxygen of this gas would seem) with a little azote\*. It is ex-

that Saussure ascertained merely that the new portion

Book IV.

tremely probable that plants, by this process, acquire the greatest part of the carbonaceous matter which they contain; for if we compare the quantity of carbon contained in plants vegetating in the dark, where this process does not go on, with the quantity which those plants contain which vegetate in the usual manner, we shall perceive a very conspicuous difference. Chaptal found that a byssus, which was vegetating in the dark, contained only  $\frac{1}{15}$ th of its weight of carbonaceous matter; but the same plant, after being made to vegetate in the light for 30 days, contained  $\frac{1}{4}$ th of its weight of carbonaceous matter<sup>a</sup>. Hassenfratz ascertained, that plants growing in the dark contain much more water, and much less carbon and hydrogen, than plants growing in the light. Sennebier analysed both with the same result. Plants growing in the dark yielded less hydrogen gas and oil: their resinous matter was to that of plants growing in the light as 2 to 5.5, and their moisture as 13 to 6; they contained even one-half less of fixed matters.

The quantity of carbonic acid thus absorbed is considerable. In Saussure's experiments, the plants absorbed daily more than their own bulk of this gas: But when they grow in the open air, where the quantity of carbonic acid is much less considerable, not exceeding  $\frac{1}{1000}$ th part, the proportion absorbed is no doubt less.

---

of gas, to which he has given the name of azote, did not diminish with oxygen, and did not render lime-water turbid. Many other gases possess these properties. It might have been some inflammable gas. Hydrogen would have detonated; but some of the compound inflammable gases would not, when diluted so largely with common air.

<sup>a</sup> *Mém. Par.* 1786.



10. Ingenhousz found that plants emit no oxygen when made to vegetate in the dark, and that in these circumstances they rather injure air than improve it. Now, as the emission of oxygen has been found to depend upon the absorption of carbonic acid, it is probable that this acid is absorbed only in the light. Saussure indeed has endeavoured to prove, that plants, even in the dark, absorb and decompose carbonic acid; but the quantity, if any, must be so extremely small, that it cannot well be appreciated.

Chap. III.

Plants emit  
no oxygen  
in the dark.

III. The green colour of plants has been shown, by Sennebier, to depend upon the absorption of carbonic acid. It appears only when plants vegetate in the light: for when they vegetate in the dark they are white; and when exposed to the light they acquire a green colour in a very short time, in whatsoever situation they are placed, even though plunged in water, provided always that oxygen be present; for Mr Gough has shown, that light without oxygen has not the power of producing the green colour\*.

Green colour  
produced by  
light.

Sennebier has observed, that when plants are made to vegetate in the dark, their etiolation is much diminished by mixing a little hydrogen gas with the air that surrounds them†. Ingenhousz had already remarked, that when a little hydrogen gas is added to the air in which plants vegetate, even in the light, it renders their verdure deeper‡: and he seems to think also, that he has proved by experiments, that plants absorb hydrogen gas in these circumstances§. Mr Humboldt has

\* *Mon. Mem.* iv. 501.

† *Encyc. Meth. Physiol. Végét.* 75.

‡ *Ann. de Chim.* iii. 57.

§ *Ibid.* 61.

Book IV.

observed that the *poa annua* and *compressa*, *plantago lanceolata*, *trifolium arvense*, *cheiranthus cheiri*, *lichen verticillatus*, and several other plants which grow in the galleries of mines, retain their green colour even in the dark, and that in these cases the air around them contains a quantity of hydrogen gas. This philosopher concludes, from his observations, that the white colour of etiolated plants is occasioned by their retaining an unusual proportion of oxygen, and that this is prevented by surrounding them with hydrogen gas. This may perhaps be true in certain cases; but the experiments of Mr Gough, mentioned above, are sufficient to prove that the retention of oxygen is not the only difference between green and etiolated plants\*.

Plants supposed to decompose water.

The green colouring matter of plants has been shown by Rouelle to be of a resinous nature. From this, and from the circumstance of its being formed only in the light, Berthollet has inferred that the leaves of plants have the property of decomposing water as well as carbonic acid when exposed to the light of the sun. The oxygen emitted, according to him, is derived partly from the decomposed carbonic acid and partly from the water, while the carbon and hydrogen enter into the composition of the inflammable parts of the plant. This ingenious theory, though sufficiently probable, is not susceptible of direct proof. From the experiments of Saussure, we learn that when plants are made to vegetate in pure water, in atmospheres destitute of carbonic acid gas, the quantity of their fixed matter de-

---

\* Plants of a white colour, from vegetating in the dark, are called *etiolated*, from a French word which signifies a star light.

not increase; but when their atmospheres contain this acid gas, the increase of weight which they receive is considerably greater than can be accounted for by the carbon and oxygen derived from the carbonic acid absorbed\*. Hence it is clear, that a portion of the water must enter into their composition. It is more likely that the elements of this portion arrange themselves in a different way, than that they still continue in the state of water. These facts certainly strengthen the hypothesis of Berthollet. Indeed, if we consider the great quantity of hydrogen contained in plants, it is difficult to conceive how they should obtain it, provided the water which they absorb does not contribute to furnish it.

Chap. III.

IV. Plants will not vegetate unless atmospheric air or oxygen gas have access to their leaves. This was rendered probable by those philosophers who, about the end of the 17th century, turned their attention particularly towards the physical properties of the air; but Dr Ingenhousz was perhaps the first of the modern chemists who put it beyond doubt. He found that carbonic acid gas, azotic, and hydrogen gas, destroyed plants altogether, unless they were mixed with atmospheric air or oxygen gas. He found also, that plants grew very well in oxygen gas and in atmospheric air†. From these experiments, it was pretty clear that the leaves of plants absorb oxygen; and the whole series of chemical experiments on plants led to the supposition that this absorption was confined to the night. The subject has lately been very fully investigated by Saus-

Plants absorb oxygen.

Book IV.

sure, who has not only confirmed these suppositions by decisive experiments, but added many new facts not previously suspected \*.

1. The greater number of plants refuse to vegetate when confined in azotic gas. Those only continue to live which are abundantly supplied with green parts, as the *cactus opuntia*, &c. When plants continue to vegetate in azote, it is because they give out a portion of oxygen during the day; the absorption of which during the night preserves them †.

2. When the leaves of plants are put in contact with common air during the night, they diminish the bulk of their atmosphere by absorbing oxygen. Some plants change, at the same time, a portion of the oxygen into carbonic acid, while others form no perceptible quantity of this last gas. The leaves, for example, of the *cactus opuntia*, *crassula cotyledon*, *semperivivum tectorum*, *agave Americana*, and *stapelia variegata*, simply absorb oxygen; while the leaves of the *quercus robur*, *indum reflexum*, *esculus hyppocastanum*, and *robinia pseudo-acacia*, absorb oxygen, and form a portion of carbonic acid, inferior in quantity to the oxygen which has disappeared ‡.

3. This inspiration of oxygen takes place only when the leaves retain their organized form. If this be destroyed, by reducing them to a paste for example, all absorption of oxygen is prevented, though a portion of it is even then converted into carbonic acid by the action of the carbonaceous matter present §.

\* Recherches, p. 60.

† Ibid. p. 197.

‡ Saussure, Ibid. p. 61.

§ Ibid. p. 74.



4. The oxygen thus inspired by the leaves of plants, not separated from them again by putting them into an exhausted receiver of the air pump. By that means, indeed, they yield a little air, but always much less than the oxygen absorbed; and this air is precisely of the same nature with the atmosphere in which they are confined. Neither is the oxygen extricated by exposing the leaves to the greatest heat which they are capable of bearing without being destroyed\*.

Chap. III.

5. There is reason to believe that the oxygen gas as absorbed by plants is converted into carbonic acid within the plant, and that it is only after the plant is saturated with this acid (if the expression may be permitted), that the surrounding oxygen is partly converted into carbonic acid, by combining with the carbonaceous matter of the plant. When the leaves are exposed to the light, this carbonic acid is decomposed, and a quantity of oxygen thrown out, usually greater than that was inspired. But the oxygen given out in the day (when plants grow in atmospheres destitute of carbonic acid) is always proportional to the oxygen inspired during the night; being always greatest when the plant has absorbed the greatest quantity of oxygen.

And convert it into carbonic acid.

Plants differ very much from each other in the quantity of oxygen which their leaves absorb during the night. Fleshy-leaved plants absorb the least oxygen, probably because they emit no carbonic acid gas. They can vegetate in high situations where the air is rarefied. Next in order come the evergreen trees, which, though they absorb more oxygen

Differ in the quantity absorbed.

\* Reaumur, p. 69.

Book IV.

than the fleshy-leaved plants, yet require much less than those trees which lose their leaves during winter. Those plants which flourish in marshy ground likewise absorb but little oxygen. The following Tables exhibit the result of Saussure's experiments on this point. The first column contains the names of the plants whose leaves were employed; the second the month in which the experiments were made; and the third the bulk of oxygen absorbed, supposing the bulk of the leaves used in each experiment to be always 1.00 \*.

Tables of  
the propor-  
tion absorb-  
ed.

I. *Leaves of Evergreen Trees.*

Leaves of	Time.	Oxygen absorbed.
Nex aquifolium .....	September .....	0.86
Buxus semper virens'..	Ditto .....	1.40
Prunus laurocerasus ...	May .....	3.20
Ditto .....	September .....	1.36
Viburnum tinus .....	September .....	2.23
Hedera helix .....	September .....	1
Vinca minor .....	June .....	1.5
Ditto .....	September .....	0.93
Pinus abies .....	September .....	3
Beupleurum fruticosum	May .....	4
Juniperus sabina .....	June .....	2.6
Juniperus communis...	June .....	2.4

---

\* Reberlet, p. 99.

II. *Leaves of Trees which lose their leaves in Winter.*

Chap. III.

Leaves of	Time.	Oxygen absorbed.
Fagus sylvatica.....	August .....	8
Carpinus betulus.....	May .....	5
Ditto .....	September .....	6
Quercus robur .....	May .....	5.5
Ditto.....	September .....	5.5
Æsculus hyppocastan. ....	September .....	4.8
Populus alba .....	May .....	6.2
Ditto.....	September .....	4.36
Prunus Armeniaca.....	September .....	8
Amygdalus Persica....	June .....	6.6
Ditto.....	September .....	4.2
Juglans regia.....	May .....	6.6
Ditto .....	September .....	4.4
Platanus occidentalis...	September .....	3
Robinia pseudo-acacia	May .....	5
Ditto .....	September .....	6.7
Syringa vulgaris .....	May .....	3.36
Ditto .....	September .....	2.2
Fraxinus excelsior....	May .....	4.32
Ditto .....	September .....	3.71
Pyrus .....	May .....	5.2
Ditto .....	September .....	3.4
Rosa centifolia .....	June .....	5.4
Fagus castanea .....	July .....	5.6

III. *Leaves of Herbaceous Plants, not Aquatic.*

Leaves of	Time.	Oxygen absorbed.
Solanum tuberosum ..	September .....	2.5
Brasica oleracea . . . .	Ditto, young leaves	2.4

## Book IV.

Leaves of	Time.	Oxygen absorbed.
<i>Brassica oleracea</i> . . . . .	Sept. old leaves . . .	2
<i>Urtica urens</i> . . . . .	September . . . . .	2
<i>Mercurialis annua</i> . . . . .	Sept. in flower . . .	2.33
<i>Daucus carota</i> . . . . .	September, ditto . . .	1.9
<i>Vicia faba</i> . . . . .	Before flowering . . .	3.7
Ditto . . . . .	In flower . . . . .	2
Ditto . . . . .	After ditto . . . . .	1.6
<i>Lilium candidum</i> . . . . .	May, in flower . . .	0.66
Ditto . . . . .	Sept. after ditto . . .	0.5
<i>Tropeolum majus</i> . . . . .	Sept. in flower . . .	3
<i>Digitalis ambigua</i> . . . . .	July . . . . .	2
<i>Brassica rapa</i> . . . . .	Sept. in flower . . .	1.25
<i>Avena sativa</i> . . . . .	June, before ditto . . .	2.7
<i>Triticum aestivum</i> . . . . .	May, before ditto . . .	5.0
<i>Pisum sativum</i> . . . . .	May, in flower . . .	3.72
<i>Ruta graveolens</i> . . . . .	August . . . . .	2

IV. *Leaves of Aquatic Plants.*

Leaves of	Time.	Oxygen absorbed.
<i>Alisma plantago</i> . . . . .	August . . . . .	0.7
<i>Inula dysenterica</i> . . . . .	September . . . . .	1.6
<i>Epilobium molle</i> . . . . .	Sept. in flower . . .	1.9
<i>Sisymbrium nasturtium</i> . . . . .	September . . . . .	1.6
<i>Polygonum Persicaria</i> . . . . .	Sept. in flower . . .	2
<i>Veronica beccabunga</i> . . . . .	September . . . . .	1.7
<i>Ranunculus reptans</i> . . . . .	September . . . . .	1.5
<i>Lythrum salicaria</i> . . . . .	May, before flower . . .	2.3
<i>Caltha palustris</i> . . . . .	May . . . . .	1
<i>Carex acuta</i> . . . . .	May . . . . .	2.25



V. *Leaves of the Fleshy Plants.*

Chap. III.

Leaves of	Time.	Oxygen absorbed.
Cactus opuntia . . .	August . . . . .	1
Agave Americana . .	August . . . . .	0.8
Sempervivum tectorum	July . . . . .	1
Sedum globosum . . .	September . . . .	1.5
Saxifraga cotyledon .	September . . . .	0.6
Sedum reflexum . . .	June . . . . .	1.7
Stapelia variegata . .	July . . . . .	0.63
Mesembryanthemum deltoides . . . . .	July . . . . .	1.7

7. It is not improbable, that by the absorption of oxygen, and the formation of carbonic acid, a portion of heat may be evolved, as Saussure supposes; though the quantity must be too small to be appreciated. It appears that in certain cases a very considerable degree of heat is produced by vegetables; though it has not yet been ascertained whether the appearance of it is connected with the absorption of oxygen. A very extraordinary instance of this is related by Bory de St Vincent on the authority of Hubert. The stamina of the *arum cardifolium*, at the moment of bursting, produced so great a heat, that twelve of them placed round the bulb of a thermometer raised it from 79° to 143°. The experiment was repeated a great number of times with similar results\*.

Heat may be evolved.

8. It appears, from the experiments of Saussure, that the roots absorb oxygen as well as the leaves, and that

Roots absorb oxygen.

\* Jour. de Phys. lxx. 281.

Book IV.

they transmit the carbonic acid formed to the leaves to be decomposed. The branches likewise absorb it. Flowers do not expand without its presence.

Thus it appears that during the night plants absorb oxygen; that they form with it carbonic acid; that a portion of this gas is sometimes emitted, together with a little azote; but that the greatest part is retained and decomposed by the leaves during the day. Plants will not live without this nightly inspiration, even though supplied with carbonic acid, provided the oxygen formed by them during the day be constantly withdrawn at the approach of night.

Leaves absorb water.

V. The leaves of plants absorb water as well as oxygen from the air. This had been suspected in all ages: the great effect which dew, slight showers, and even wetting the leaves of plants, have in recruiting their strength, and making them vegetate with vigour, are so many proofs that the leaves imbibe moisture from the atmosphere. Hales rendered this still more probable, by observing that plants increase considerably in weight when the atmosphere is moist; and Mr Bonnet put the matter beyond doubt in his *Researches concerning the Use of the Leaves*. He showed that leaves continue to live for weeks when one of their surfaces is applied to water; and that they not only vegetate themselves, but even imbibe enough of water to support the vegetation of a whole branch, and the leaves belonging to it. He discovered also, that the two surfaces of leaves differ very considerably in their power of imbibing moisture; that in trees and shrubs the under surface possesses almost the whole of the property, while the contrary holds in many of the other plants; the kidney bean for instance.

These facts prove not only that the leaves of plants have the power of absorbing moisture, but also that the absorption is performed by very different organs from those which emit moisture ; for these organs lie on different sides of the leaf. If we consider that it is only during the night that the leaves of plants are moistened with dew, we can scarcely avoid concluding, that, except in particular cases, it is during the night that plants imbibe almost all the moisture which they do imbibe.

Thus we have seen that the leaves of plants perform very different operations at different times. During the day they are giving out moisture, absorbing carbonic acid gas, and emitting oxygen gas ; during the night, on the contrary, they are absorbing moisture, giving out carbonic acid gas, and absorbing oxygen gas.

By these processes, and perhaps also by others which have not yet been detected, the sap of plants is new modelled, and brought to the state which is adapted for the nourishment of the plant. To describe in what manner these changes take place is impossible ; because we neither know precisely the substance into which the sap has been converted by the operations performed during the day, nor the new substances formed by the operations of the night. We have reason, however, to conclude, that during the day the carbon of the sap is increased, and that during the night the hydrogen and oxygen are increased ; but the precise new substances formed are unknown to us. Nor let any one suppose that the increase of the hydrogen and of the oxygen of the sap is the same thing as the addition of a quantity

Sap converted into nutritive juices by these processes.

Book IV.

of water. In water, oxygen and hydrogen are already combined together in a certain proportion ; and this combination must be broken before these elementary bodies can enter into those triple compounds with carbon, of which a great part of the vegetable products consist. We have not the smallest conception of the manner in which these triple combinations are formed, and as little of the manner in which the bodies which compose vegetable substances are combined together. The combination, may, for any thing we know to the contrary, be very complicated : though it consists only of three ingredients ; and analogy leads us to suppose that it actually is very complicated : for in chemistry it may be considered as a truth, to which at present few or no exceptions are known, that bodies are decomposed with a facility inversely as the simplicity of their composition ; that is to say, that those bodies which consist of the fewest ingredients are most difficultly decomposed, and that those which are formed of many ingredients are decomposed with the greatest facility.

Neither let any one suppose that the absorption of carbonic acid gas during the day is balanced by the quantity emitted during the night ; and that therefore there is no increase of carbon : for Ingenhousz and Senebier have shown that the quantity of oxygen gas emitted during the day is much greater than the carbonic acid gas emitted during the night ; and that in favourable circumstances, the quantity of oxygen gas in the air surrounding plants is increased, and the carbonic acid gas diminished ; so much so, that both Dr Priestley and Dr Ingenhousz found, that air which had been spoiled by a lighted candle, or by animals, was rendered as good as ever by plants. Now we know that com-



bustion and respiration diminish the oxygen gas, and add carbonic acid gas to air; therefore vegetation, which restores the purity of air altered by these processes, must increase the oxygen, and diminish the carbonic acid gas of that air; consequently the quantity of carbonic acid gas absorbed by plants during the day is greater than the quantity emitted by them during the night; and of course the carbon of the sap is increased in the leaves.

It is true, that when plants are made to vegetate for a number of days in a given quantity of air, its ingredients are not found to be altered. Thus Hassenfratz ascertained that the air, in which young chesnuts vegetated for a number of days together, was not altered in its properties, whether the chesnuts were vegetating in water or in earth<sup>\*</sup>; and Saussure junior proved that peas growing for ten days in water did not alter the surrounding air<sup>†</sup>. But this is precisely what ought to be the case, and what must take place, provided the conclusions which I have drawn be just. For if plants only emit oxygen gas by absorbing and decomposing carbonic acid gas, it is evident, that unless carbonic acid gas be present, they can emit no oxygen gas; and whenever they have decomposed all the carbonic acid gas contained in a given quantity of air, we have no longer any reason to look for their emitting any more oxygen gas; and if the quantity of carbonic acid gas emitted during the night be smaller than that absorbed during the day, it is evident that during the day the plant will constantly decompose all the acid which had been form-

---

<sup>\*</sup> *Ann. de Chim.* xiii. 325.

<sup>†</sup> *Ibid.* xxiv. 139.

Book IV.

ed during the night. By these processes the mutual changes of day and night compensate each other; and they are prevented from more than compensating each other by the forced state of the plant. It is probable, that when only part of a plant is made to vegetate in this forced state, some *carburated sap* (if I may be allowed the expression) is supplied by the rest of the plant; and that therefore the quantity of carbonic acid gas emitted during the night may bear a nearer proportion to that emitted in a state of nature than that of the absorption of fixed air can possibly do. And probably, even when the whole plant is thus confined, the nightly process goes on for a certain time at the expense of the carbon already in the sap; for Hassenfratz found, that in these cases the quantity of carbon in the plant, after it had vegetated for some time in the dark, was less than it had been when it began to vegetate\*. This is the reason that plants growing in the dark, when confined, absorb all the oxygen gas, and emit carbonic acid gas: and whenever this has happened, they die; because then neither the daily nor nightly processes can go on.

---

### SECT. V.

#### OF THE PECULIAR JUICES OF PLANTS.

By these changes which go on in the leaves, the nature of the sap is altogether changed. It is now con-

---

\* *Ann. de Chim.* xlii. 183.

into what is called the *peculiar juice*, or *true sap*, fit for being assimilated to the different parts of the plant, and for being employed in the formation of secretions which are necessary for the purposes of vegetable economy. Chap. III.

Leaves, therefore, may be considered as the digesting organs of plants. The leaves are not mere ornaments; they are the important parts of the plant. Accordingly we find, whenever we strip a plant of its leaves, we strip it of its vegetating powers till new leaves are formed.

It is well known that when the leaves of a plant are destroyed by insects they vegetate no longer, but their fruit never makes any farther progress in its growth, but decays and dries up. Even in germination progress is made in the growth of the stem till the seed-leaves appear. As much food indeed is laid up in the cotyledons as advances the plant to a certain point, where the root is prepared, and made ready to perform its functions; but the sap which it imbibes must be carried to the seed-leaves, and digested there, before it is proper for forming the plumula into a stem. If the seed-leaves are cut off, the plant re-vegetate.

It will be very natural to ask, If this be true, how are the leaves themselves to be produced? I had endeavored to render it probable, that food for the purpose of nourishing and developing them was laid up in the cotyledons themselves; but the late experiments of Mr. Sowerby, formerly detailed, have shown that the albumen is the part of the tree in which this food is deposited. After the plant has developed all the parts

Leaves the  
digesting  
organs of  
plants.

How they  
are produced.

Book IV.

which are to appear during the summer, and after the buds are fabricated and rolled up, the leaves still continue to manufacture new food, and to send it to the alburnum. Here it is deposited, and employed next spring in feeding and developing those organs of plants which are absolutely necessary for enabling them to perform the functions of vegetation. From this important fact, Mr Knight has drawn a number of curious consequences, of great importance to the practical gardener and farmer.

This deposition of food for the future supply of the plant, explains to us why the branch of a vine, if it be introduced into a hot-house during the winter, puts forth leaves and vegetates with vigour, while every other part of the plant gives no signs of life. It explains to us also why the sap flows out of trees very readily in spring before the leaves appear, but after that the bleeding ceases altogether. It is evident that there can be scarcely any circulation of sap before the leaves appear; for as there is no outlet, when the vessels are once full they can admit no more. It appears, however, from the bleeding, that the roots are capable of imbibing, and the vessels of circulating, the sap with vigour. Accordingly, whenever there is an outlet, they perform their functions as usual, and the tree bleeds; that is, they send up a quantity of sap to be digested as usual: but as there are no digesting organs, it flows out, because the sap that flows out would not have been imbibed at all, had it not been for the artificial opening. But when the digestive organs appear, the tree will not bleed; because these organs require all the sap, and it is constantly flowing to them.

If a tree be deprived of its leaves, new leaves make



their appearance, because they are already prepared for that purpose. But what would be the consequence if a tree were deprived of its leaves and of all its buds for five years back? That plants do not vegetate without leaves is evident from an experiment of Duhamel. He stripped the bark off a tree in ringlets, so as to leave five or six rings of it at some distance from each other, with the bark in the intervals. Some of these rings had buds and leaves; these increased considerably in size; but the ring which had none of these remained for years unaltered. Mr Knight found that a shoot of the vine, when deprived of its leaves died altogether\*.

Chap. III.  
Absolutely  
necessary.

The *succus proprius*, or *peculiar juice* of plants may be considered as analogous to the blood of animals. It is the food altered by digestion, and rendered fit for being assimilated and converted into a part of the plant itself by the subsequent processes of vegetation. That it flows from the leaves of the plant towards the roots appears from this circumstance, that when we make an incision into a plant, into whatever position we put it, more of the *succus proprius* flows from that side of the wound which is next the leaves and branches than from the other side: and this happens even though the leaves and branches be held undermost†. When a ligature is tied about a plant, a swelling appears above and not below the ligature.

Form the  
peculiar  
juice,

Which  
flows from  
the leaves

The vessels containing the peculiar juice have been discovered by Mr Knight from the leaves into the cortical part of the inner bark‡. Hedwig, who has examined the vessels of plants with very great care, seems to con-

In vessels.

\* A. Trans. 1801, p. 338.    † Bell, Manch. Mem. ii. 402.  
‡ A. Trans. 1801, p. 337.

Book IV.

sider them as of the same structure with the tracheæ, but Mr Knight is of a different opinion. It appears evidently from the experiments of this last gentleman, that they communicate with no part of the plant which is situated at a greater distance from the root than the leaf from which they themselves originate. For when two circular incisions are made through the bark of a branch above and below a leaf, and at some distance from it, only that part of the portion confined between the two incisions which is situated below the leaf increases in size. From the late experiments of Mr Knight, there is reason to believe that these vessels are much better calculated to carry the true sap from the leaves towards the roots, than in the contrary direction. By passing the slender shoots of a vine through the earth of a garden-pot, he made them send out roots. The shoots were then cut off from the parent tree, leaving an equal portion on each side of this new root. Each of these portions was turned up at a similar angle, and had a bud at a little distance from the cut-off extremity. Here were two stems growing from one root. But the one was obviously inverted, while the other was in its natural position. In the first, the wood between the bud and the cut-off extremity increased in size; but in the other it did not: indicating a disposition in the true sap to move in its original direction from the leaves to the root. In like manner, when shoots of gooseberry and currant bushes were planted inverted, the upper part always decayed\*. These experiments are favourable to the opinion, that these vessels are furnished with valves.

---

\* Nicholson's *Jour.* x. 289.

all communication between the leaves and cut off, by removing a portion of the bark all the tree, it appears, from the experiments of that the alburnous vessels acquire the property of admitting a portion of the true sap to the roots, to maintain the powers of vegetating; but the power is greatly diminished. The surplus appears lodged in the alburnum, which thus becomes swollen, and if the plant be allowed to vegetate, this is expended next season upon the upper part of the tree. Thus the quantity of blossom on the branch of a simple tree is greatly increased by removing a section of its bark the season before the blossom is to appear.

The true sap is easily known by its colour and its consistence. In some plants it is green, in some red, in some milky. It cannot be doubted that its motion in the vessels is performed in the same way as that of

its properties.

Had any method of obtaining this peculiar juice of purity, the analysis of it would throw a great deal of light upon vegetation; but this is scarce, as we cannot extract it without dividing at the same time the vessels which contain the sap. In many cases, however, the peculiar juice may be known by its colour and then its analysis may be performed with an approach towards accuracy. The facts respecting its properties, hitherto ascertained by chemists, have, as far as I am acquainted with them, been detailed in the foregoing Chapter. These experiments prove, as might

Book IV.

have been expected, that the peculiar juices differ very considerably from each other, and that every plant has a juice peculiar to itself. Hence it follows, that the processes which go on in the leaves of plants must differ at least in degree, and that we have no right to transfer the conclusions deduced from experiments on one species of plants to those of another species. It is even probable, that the processes in different plants are not the same in kind; for it is not reasonable to suppose that the phenomena of vegetation in an agaric or a boletus are precisely the same as those which take place in trees and in larger vegetables, on which alone experiments have hitherto been made.

The true sap is conveyed to every part of the plant; and all the substances which we find in plants, and even the organs themselves by which they perform their functions, are formed from it. But the thickest veil covers the whole of these processes; and so far have philosophers hitherto been from removing this veil, that they have not even been able to approach it. All these operations indeed, are evidently chemical decompositions and combinations; but we neither know what these decompositions and combinations are, nor the instruments in which they take place, nor the agents by which they are regulated.



## SECT. VI.

## OF THE DECAY OF PLANTS.

as far as I am acquainted with them, are the  
 es produced by vegetation. But plants do not  
 ue to vegetate for ever; sooner or later they de-  
 ad wither, and rot, and are totally decomposed.  
 change indeed does not happen to all plants at the  
 the same time. Some live only for a single sea-  
 even for a shorter period; others live two sea-  
 others three, others a hundred or more; and there  
 me plants which continue to vegetate for a thou-  
 ears; but sooner or later they all cease to live;  
 en those very chemical and mechanical powers  
 had promoted vegetation combine to destroy the  
 of the plant. Now, What is the cause of this

Plants de-  
 cay and die.

Why do plants die?

question can only be answered by examining  
 ne care what it is which constitutes the *life* of  
 or it is evident, that if we can discover what  
 which constitutes the life of a plant, it cannot be  
 discover whatever constitutes its death.

the phenomena of vegetable life are in general

Phenomena  
 of vegetable  
 life

As long as a plant continues to vegetate,  
 it lives; when it ceases to vegetate, we  
 at it is dead.

of vegetables, however, is not so intimately  
 with the phenomena of vegetation that they  
 separated. Many seeds may be kept for  
 giving any symptom of vegetation; yet

#### VEGETATION:

Many vegetables when put into the earth, we say they possess life; and if we would speak accurately, we may also say that they possessed life even before they were put into the earth: for it would be absurd to suppose that the seed obtained life merely by being put into the earth. In like manner many plants decay, and give no symptoms of vegetation during winter; yet when they vegetate when the mild temperature of spring affects them, we consider them as having lived all winter. The life of plants, then, and the phenomena of vegetation, are not precisely the same thing; for the one may be separated from the other, and we can even suppose the one to exist without the other. Nay, what is more, we can, in many cases, *decide*, without hesitation, that a vegetable is not dead, even when no vegetation appears; and the proof which we have for its life is, that it *remains unaltered*; for we know that when a vegetable is dead, it soon changes its appearance, and falls into decay.

Thus it appears that the *life* of a vegetable consists in two things: 1. In remaining unaltered, when circumstances are unfavourable to vegetation; 2. In exhibiting the phenomena of vegetation when circumstances are favourable. When neither of these two things happens, we may say that a vegetable is dead.

The phenomena of vegetation have been enumerated above. They consist in the formation or expansion of the organs of the plant, in the taking in of nourishment, in carrying it to the leaves, in digesting it, in distributing it through the plant, in augmenting the bulk of the plant, in repairing decayed parts, in forming new organs when they are necessary, in producing seeds capable of being converted into plants similar to the pa-

rent. The *cause* of these phenomena, whatever it may be, is the *cause* also of *vegetable life*, and may be distinguished by the name of the *vegetative principle*. But an inquiry into the nature of this principle belongs to the science of *physiology*, and would be foreign to the nature of this Work.

Chap. III.

Owing to a vegetative principle.

The death of plants, if we can judge from the phenomena, is owing to the organs becoming at last altogether unfit for performing their functions, and incapable of being repaired by any of the powers which the vegetative principle possesses. The changes which vegetable substances undergo after death come now to be examined. They shall form the subject of the ensuing Chapter.

Death of plants.



## Book IV.

## CHAP. IV.

## OF THE DECOMPOSITION OF VEGETABLE SUBSTANCES.

Difference  
between  
minerals  
and living  
matter.

THE most striking distinction between the substances belonging to the mineral kingdom and those which make a part of animals or vegetables, is the following. Mineral bodies show little or no tendency to change their nature; and when left to themselves, undergo no spontaneous decompositions: whereas animal and vegetable substances are continually altering; and when left to themselves in favourable circumstances, always run through a regular set of decompositions. I propose in this Chapter to treat of the spontaneous decompositions of vegetable bodies; those of animal bodies belong to the next Book.

Vegetable  
substances  
go through  
a series of  
changes.

We have seen in the last Chapter, that during vegetation the constituents of plants are continually going through a regular set of changes, losing the properties of one substance, and assuming those of another. Thus a substance which in the young plant has the properties of mucilage, assumes in the old the properties of starch: what in green fruit is an acid, in ripe fruit becomes



gari. Vegetable principles, then, are not fixed or stationary in the living plant; they are gradually running to one another. But this tendency to change, or rather this continual decomposition in consequence of the mutual reaction of the different simple substances of which the vegetable principles are composed, is by no means confined to the living state. It goes on with equal or with greater energy in favourable circumstances in vegetable matter after it has been completely separated from the living plants. It has been observed that this tendency to spontaneous decomposition is usually greater in animal than in vegetable bodies; and that those vegetable bodies, in which the tendency is greatest, bear the closest resemblance to animal matter. Hence the common chemical phrase, that such substances are *more animalised*. This is the case with *glucose* in particular, which undergoes spontaneous decomposition more rapidly than most other vegetable bodies.

During the spontaneous decomposition which vegetable substances undergoes, it is obvious that the simple substances of which they are composed must unite together in a different manner from that in which they were formerly united, and form a new set of compounds which did not formerly exist. Now it has been observed that the specific gravity of these new compounds is almost always less than that of the old body. Some of them usually fly off in the state of gas or vapour. Hence the odour that vegetable bodies emit during the whole time that they are running through the series of their changes. When the odour is very offensive or noxious, the spontaneous decomposition is called *putrefaction*; but when the odour is not offensive, or when

These spontaneous alterations.

Book IV.

Called *fermentation*.

any of the new compounds formed is applied to useful purposes, the spontaneous decomposition is called *fermentation*. This word was first introduced into chemistry by Van Helmont \*. It is supposed by some to have originated from the intestine motion which is always perceptible while vegetable substances are fermenting; while by others it is derived from the heat which in these cases is always generated. The term *fermentation* is now very often applied to all the spontaneous changes which vegetable bodies undergo without regard to the products. It therefore, in that sense, includes *putrefaction*; and certainly there is no impropriety in thus extending the term so as to make it comprehend every case of spontaneous decomposition. By fermentation, then, is now meant all the spontaneous changes which take place in vegetable substances after they are separated from the living plant.

All the phenomena of fermentation lay for many years concealed in the completest darkness, and no chemist was bold enough to hazard even an attempt to explain them. They were employed, however, and without hesitation too, in the explanation of other phenomena; as if giving to one process the name of another, of which we are equally ignorant, could, in reality, add any thing to our knowledge. The darkness which enveloped these phenomena has lately begun to disperse; but they are still surrounded with a very thick mist; and we must be much better acquainted with the composition of vegetable substances, and the mutual affini-

---

\* Stahl's *Fundament, Chem.* i. 124.

their ingredients, than we are at present, before Chap. IV.  
explain them in a satisfactory manner.

mentation never takes place unless vegetable substances contain a certain portion of water, and unless they are exposed to a temperature at least above the freezing point. When dry or freezing, many of them remain long without alteration. Hence we have an easy method of preventing fermentation.

We take a view of all the vegetable principles described in the first Chapter of this Book, we shall find they differ much from one another in their tendency into fermentation. Gum, sarcocol, starch, indigo, resins, camphor, caoutchouc, gum resins, wood, &c. though mixed with water, and placed in the most favourable temperature, show scarcely any tendency to change their nature. Oils absorb oxygen from the atmosphere but too slowly to produce any intestine fermentation. Tannin, some of the acids, and extractive, are gradually decomposed; the surface of the liquid becomes mouldy, and an insipid sediment falls to the bottom, and when the process has once begun, it goes on with greater rapidity. Albumen and fibrin putrefy very rapidly, but the products have not been ascertained; casein gradually changes into a kind of cheese.

Tendency  
differs in  
different  
bodies.

It is when several of the vegetable principles are mixed together, that the fermentation is most perfect, and the change most remarkable. Thus when yeast is added to a solution of sugar in water, the liquor soon runs into vinegar, or in certain cases to alcohol and vinegar. When gluten is mixed with starch in water, alcohol and vinegar usually make their appearance; but the greatest part of the starch remains unaltered. It has been observed that certain substances

Greatest in  
compounds.



Book IV. are peculiarly efficacious in exciting fermentation in others. These substances have received the name of *ferments*.

But the phenomena of fermentation do not appear in their greatest perfection in our artificial mixture of vegetable principles. Those complicated parts of plants in which various principles are already mixed by Nature, especially the liquid parts, exhibit the finest specimens of it; such as the sap of trees, the juices of fruits, the decoctions of leaves, seeds, &c. It is from such natural mixtures that we obtain all the products of fermentation which mankind have applied to useful purposes; such as indigo, beer, bread, vinegar, wine, &c. In the present imperfect state of the subject, I shall satisfy myself with an account of the most important of these products of fermentation, and of the phenomena which take place during their formation.

*Division.* I shall divide this Chapter into four Sections: In the first, I shall treat of the fermentation which takes place during the making of bread; in the second, of the fermentation which produces intoxicating liquors; in the third, of the fermentation which produces vinegar; and in the fourth, that which reduces the substance to *oil*. These are usually called the *panary*, *vinous*, *acetic*, and *putrefactive* fermentations.



---

---

SECT. I.

## OF THE PANARY FERMENTATION.

As the manufacture of bread may appear to us to have been always accustomed to consider it as a long process, its discovery was probably the work of ages, and the result of the united efforts of men, sagacity, had they lived in a more fortunate period of society, would have rendered them the rivals of Columbus or of Newton.

Discovery  
of bread.

The method of making bread similar to ours was known in the East at a very early period ; but neither the precise time of the discovery, nor the name of the person who published it to the world, has been preserved.

We are certain that the Jews were acquainted with it in the time of Moses : for in Exodus \* we find prohibition to use leavened bread during the celebration of the passover. It does not appear, however, to have been known to Abraham ; for we hear, in his history, of cakes frequently, but nothing of leaven. Egypt, from the nature of the soil and the early period at which it was civilized, bids fairest for the discovery of the art of making bread. It can scarcely be doubted that the

---

\* Chap. xii. v. 15.

## Book IV

Jews learned the art from the Egyptians. The Greeks assure us that they were taught the art of making bread by the god Pan. We learn from Homer that it was known during the Trojan war \*. The Romans were ignorant of the method of making bread till the year 580 after the building of Rome, or 200 years before the commencement of the Christian era †. Since that period the art has never been unknown in the south of Europe; but it made its way to the north very slowly, and even at present, in many northern countries, fermented bread is but very seldom used.

Substances  
which make  
bread.

The only substance well adapted for making bread, I mean *loaf bread*, is wheat flour, which is composed chiefly of *starch* and *gluten*, but contains also some *mucilage* and *saccharine matter*. It is to the gluten that wheat flour owes its superiority to every other as the basis of bread. Indeed there are only two other substances at present known of which loaf bread can be made; these are *rye* and *potatoes*. The rye loaf is by no means so well raised as the wheat loaf; and potatoes will not make bread at all without particular management. Potatoes, previously boiled and reduced to a very fine tough paste by a rolling pin, must be mixed with an equal weight of potatoe starch. This mixture, according to Permentier, if baked in the usual way, makes a very white, well raised, pleasant bread.

Method of  
baking  
bread.

The baking of bread consists in mixing wheat flour with water, and forming it into a paste. The average proportion of these is two parts of water to three of flour. But this proportion varies considerably, accord-

\* Iliad, ix. 216.

† Pliny, lib. xviii. cap. 11.

the age and the quality of the flour. In general, the finer and the better the flour is, the greater is the quantity of water required. If the paste, after being mixed, be allowed to remain for some time, its ingredients gradually act upon each other, and the paste acquires new properties. It gets a disagreeable sourness, and a quantity of carbonic acid gas is evolved. In this state, the paste ferments\*. These changes do not take place without water; that liquid, therefore, is a necessary agent.

The fermented dough is known by the name of *leaven*. From the experiments of Mr Edlin, it appears that during this fermentation the temperature of the dough increases, and that a quantity of vinegar is formed. A pound avoirdupois of flour mixed with half its weight of water, and set in a warm place to ferment for six hours, generated as much vinegar as required to be mixed with carbonate of potash to neutralize it†.

The dough, after standing for a sufficient time to ferment, if baked in the usual way, it forms a loaf full of gas, but of a taste so sour and unpleasant that it cannot be eaten. If a small quantity of this dough, or *leaven* as it is called, be mixed with new flour, the whole begins to ferment in a short time, and a quantity of gas is evolved: but the glutinous nature of the flour renders the paste so tough that the gas cannot escape; it therefore causes the paste to swell in proportion: and if it be now baked into loaves, the number of air bubbles imprisoned in every

---

\* From this process that Van Helmont transferred the word *ferment* into chemistry.

† See *Treatise on the Art of Bread-Making*, p. 78.

Book IV.

part renders the bread quite full of eyes, and very light. If the precise quantity of leaven necessary to produce the fermentation, and no more, has been used, the bread is sufficiently light, and has no unpleasant taste; but if too much leaven be employed, the bread has a bad taste; if too little, the fermentation does not come on, and the bread is too compact and heavy. To make good bread with leaven therefore is difficult. Mr Edlin, however, has suggested a method, which, if it do not injure the taste of the bread, may be practised with great facility, and it even improves the lightness of bread. It consists in adding a sufficient quantity of carbonate of potash to neutralize the acetic acid, and to knead the alkali rapidly into the dough, so as to prevent, as much as possible, the carbonic acid disengaged from escaping \*.

Fermentation promoted by  
barm.

The ancient Gauls had another method of fermenting bread. They formed their paste in the usual way; and, instead of leaven, mixed with it a little of the *barm* which collects on the surface of fermenting beer†. This mixture produced as complete and as speedy a fermentation as leaven; and it had the great advantage of not being apt to spoil the taste of the bread. About the end of the 17th century, the bakers in Paris began to introduce this practice into their processes. The practice was discovered, and exclaimed against; the faculty of medicine, in 1688, declared it prejudicial to health; and it was not till after a long time that the bakers succeeded in convincing the public that bread baked with

\* Edlin's *Treatise on the Art of Bread-Making*, p. 79.

† Pliny, lib. xviii. cap. 7.



is superior to bread baked with leaven. In this  
ry the bread has for these many years been fer-  
d with barm.

What is this barm which produces these effects? Mr  
y of Manchester has proved, by a number of very  
esting experiments, that carbonic acid is capable of  
employed in many cases with success as a substi-  
or barm \*. Edlin informs us, that when dough  
ed with water impregnated with carbonic acid, the  
ises precisely as when yeast is used; and he assures  
at yeast, previously deprived of its carbonic acid  
at, has no efficacy in raising bread; but that it  
in the usual way, and becomes full of eyes, if the  
us separated be again added †. Hence he con-  
s that carbonic acid is the only essential consti-  
of yeast, as far as the *raising* of bread is con-  
l.

at the presence of carbonic acid, or of some simi-  
s, is essential, cannot be doubted; but there is  
to doubt the assertion, that yeast, after being de-  
l of its carbonic acid, will not afterwards, when  
ened, generate a sufficient quantity to answer all  
rposes required. It has been customary with the  
s of Paris to bring their barm from Flanders and  
ly in a state of dryness. When skimmed off the  
it is put into sacks, and the moisture allowed to  
out; then these sacks are subjected to a strong  
ure, and when the barm is dry it is made up into  
t. Now this process must separate the carbonic

\* *Manch. Mem.* ii. 162.

† Edlin's *Treatise on the Art of Bread-Making*, p. 54.

‡ *Encycl. Method. Arts et Met.* i. 249.

Book IV. acid; yet this barm, when again moistened, ferments bread equally well with new barm.

After the bread has fermented, and is properly raised, it is put into the oven previously heated, and allowed to remain till it be baked. The mean heat of an oven, as ascertained by Mr Tillet, is  $448^{\circ}$ . The bakers do not use a thermometer: but they judge that the oven has arrived at the proper heat when flour thrown on the floor of it becomes black very soon without taking fire. We see, from Tillet's experiment, that this happens at the heat of  $448^{\circ}$ .

Quantity of  
bread from  
a given  
weight of  
flour.

A sack of flour containing five bushels, and weighing 280 lbs. avoirdupois, is in this country made, at an average, into 80 quartern loaves. Hence  $3\frac{1}{2}$  lbs. of flour go to every loaf. From the evidence laid before a Committee of the House of Commons in 1804, we learn that for this quantity of flour five pounds avoirdupois of common salt, and about three English pints of good yeast, are allowed. There is reason to believe, also, that about an ounce of alum, previously dissolved in water, is mixed with the yeast †. After the dough has been properly kneaded and fermented, it is divided into masses, weighing each 4 lbs. 15 ounces avoirdupois; the quantity of wet dough allowed for a quartern loaf. It is then put into the oven, and when sufficiently baked is withdrawn. By the laws of this country, every quartern loaf must weigh 4 lbs.  $5\frac{1}{2}$  ounces avoirdupois. Hence we see that it loses about  $11\frac{1}{2}$  ounces while in the oven. The number of loaves obtained from a sack of flour varies a good deal; sometimes 82

\* *Encyc. Method. Arts et Metiers*, i. 275.

† Edlin, p. 90.

can be made from it, sometimes scarcely 80, depending obviously on the quality of the flour \*.

Chap. IV.

It appears, from the report of the commissioners of French Academy in 1783, that French bread loses more weight than what has been above stated.

Loss sustained in the oven.

Tillet, and the other commissioners who were appointed to examine this subject in consequence of a petition from the bakers of Paris, found that a loaf, when weighed before it was put into the oven 4·625 pounds, after being taken out baked, weighed, at an average, only 3·813 pounds, or 0·812 pound less than paste. Consequently 100 parts of paste lose, at an average, 17·34 parts, or somewhat less than  $\frac{1}{7}$ th, by being baked. They found, however, that this loss of weight was by no means uniform, even with respect to those loaves which were in the oven at the same time, of the same form, and in the same place, and which were put in and taken out at the same instant. The greatest difference in these circumstances amounted to 2889, or 7·5 parts in the hundred, which is about  $\frac{1}{13}$ th of the whole. This difference is very considerable, and it is not easy to say to what it is owing. It is evident, that if the paste has not all the same degree of maturity, and if the barm be not accurately mixed throughout the whole, if the fermentation of the whole be not precisely the same, that these differences must take place. Now, it is needless to observe how difficult it is to perform all this completely. The French commissioners found, as might indeed have been expected,

---

For a minute description of the method of baking bread, the reader is referred to Eolin's *Treatise on Bread-Making*, p. 90. *Encyc. Method. Arts et Metiers*, i. 275.



Book IV.

that, other things being equal, the loss of weight sustained is proportional to the extent of surface of the loaf, and to the length of time that it remains in the oven; that is to say, the smaller the extent of the external surface, or, which is the same thing, the nearer the loaf approaches to a globular figure, the smaller is the loss of weight which it sustains; and the longer it continues in the oven, the greater is the loss of weight which it sustains. Thus a loaf which weighed exactly four pounds when newly taken out of the oven, being replaced as soon as weighed, lost, in ten minutes,  $\cdot 125$  pound of its weight, and in ten minutes more it again lost  $\cdot 0625$  pound\*.

Loaves are heaviest when just taken out of the oven; they gradually lose part of their weight, at least if not kept in a damp place, or wrapt round with a wet cloth†. Thus Mr Tillet found that a loaf of four pounds, after being kept for a week, wanted  $\cdot 3125$ , or nearly  $\frac{1}{4}$ th of its original weight‡.

Properties  
of bread.

When bread is newly taken out of the oven, it has a peculiar, and rather pleasant smell, which it loses by keeping, unless its moisture be preserved by wrapping it round with a wet cloth; as it does also the peculiar taste by which new bread is distinguished. This shows us that the bread undergoes chemical changes; but what these changes are, or what the peculiar substance is to which the odour of bread is owing, is not known.

Bread differs from the flour of which it is made, for

---

\* *Encyc. Method.* art. i. 270.

† This is an excellent method of preserving bread fresh, and free from mould for a long time.

‡ *Encyc. Method.* art. i. 270.



none of the ingredients of the flour can now be discovered in it. The only chemist who has attempted an analysis of bread is Mr Geoffroy. He found that 100 parts of bread contained the following ingredients:

Chap. IV.

Constitu-  
ents of  
bread.

24·735 water

32·030 gelatinous matter, extracted by boiling water

39·843 residuum insoluble in water

---

96·608

3·392 loss

---

100·000

But this analysis, which was published in the *Memoirs of the French Academy* for the year 1732, was made at a time when the infant state of the science of chemistry did not admit of any thing like accuracy. It is by no means improbable, that if bread were to be examined with care, both the gluten and starch might still be detected, though perhaps it would be difficult to separate them.

---

## SECT. II.

### OF THE VINOUS FERMENTATION.

UNDER this name is comprehended every species of fermentation which terminates in the formation of an intoxicating liquid. Now these liquids, though numerous, may be comprehended under two general heads; namely, those which are obtained from the *de-*

Book IV. *portions of seeds, and those which are obtained from the juices of plants. The liquids of the first class are denominated beer or wash, those of the second wine.*

### I. BEER.

The method of making beer was known in the most remote ages. The Greek writers give the honour of the invention to the Egyptians. Almost every species of corn has been employed for the purpose. In Europe it is usually made from barley, in India from rice, in the interior of Africa from the *bolcus spicatus*\*; but whatever grain is employed, the process is nearly the same. We shall therefore select, as an example, the beer made in this country from *barley*.

1. As the grain in its natural state has been found unsuitable for yielding good beer, it is usual, in the first place, to convert it into *malt*.

**Malt.** The term *malt* is applied to grain which has been made to germinate artificially to a certain extent, after which the process is stopped by the application of heat.

**Steeping of barley.** The barley is steeped in cold water for a period which (as regulated by law) must not be less than 40 hours; but beyond that period the steeping may be continued as long as is thought proper. Here it imbibes moisture, and increases in bulk; while at the same time a quantity of carbonic acid is emitted, and a part of the substance of the husk is dissolved by the steep-water. The proportion of water imbibed depends

---

\* Park's Travels, p. 63, 8vo Edition.

y on the barley, and partly on the length of time it is steeped. From the average of a good many, it appears that the medium increase of weight, steeping, may be reckoned 0.47; that is to say, 100 pounds of barley when taken out of the water weighs 147 pounds. The average increase of bulk is about a fifth; that is to say, that 100 bushels of barley, after being steeped, swell to the bulk of 120 bushels. The carbonic acid emitted while the barley is steeping is inconsiderable; and it is probable, from experiments of Saussure, that it owes its formation, at least in part, to the oxygen held in solution by the water.

The steep-water gradually acquires a yellow colour, and the peculiar smell and taste of water in which barley has been steeped. The quantity of matter which holds in solution varies from  $\frac{1}{100}$ th to  $\frac{1}{1000}$ th of the weight of the barley. It consists chiefly of an extract-matter of a yellow colour and disagreeable bitter taste, which deliquesces in a moist atmosphere, and contains always a portion of nitrate of soda. It holds in solution most of the carbonic acid disengaged. This active matter is obviously derived from the husk of the barley, and is the substance to which that husk owes its colour. Accordingly grain becomes much discoloured by steeping.

After the grain has remained a sufficient time in the water, the water is drained off, and the barley thrown out of the cistern upon the malt-floor, where it is formed into a rectangular heap, called the *couch*, about 16 inches deep. In this situation it is allowed to remain for 26 hours. It is then turned, by means of wooden rakes, and diminished a little in depth. This turn-

Couch.



Book IV. ing is repeated twice a-day or oftener, and the grain is spread thinner and thinner, till at last its depth does not exceed a few inches.

Changes  
while on  
the malt-  
floor.

When placed on the couch, it begins gradually to absorb oxygen from the atmosphere, and to convert it into carbonic acid; at first very slowly, but afterwards more rapidly. The temperature, at first the same with that of the external air, begins slowly to increase; and in about 96 hours the grain is, at an average, about  $10^{\circ}$  hotter than the surrounding atmosphere. At this time the grain, which had become dry on the surface, becomes again so moist that it will wet the hand, and exhales at the same time an agreeable odour, not unlike that of apples. The appearance of this moisture is called *sweating*. A small portion of alcohol appears to be volatilized at this period. The great object of the maltmen is to keep the temperature from becoming excessive. This they do by frequent turning. The temperature which they wish to preserve varies from  $55^{\circ}$  to  $62^{\circ}$ , according to the different modes of malting pursued.

At the period of the sweating the roots of the grains begin to appear, at first like a small white prominence, at the bottom of each seed, which soon divides itself into three rootlets, and increases in length with very great rapidity, unless checked by turning the malt. About a day after the sprouting of the roots, the rudiments of the future stem, called *acrospire* by the maltsters, may be seen to lengthen. It rises from the same extremity of the seed with the root, and advancing within the husk, at last issues from the opposite end: but the process of malting is stopped before it has made such progress.

As the acrospire shoot the grain, the appear.



kernel, or mealy part of the corn, under-  
derable change. The glutinous and muc-  
atter is taken up and removed, the colour  
ite, and the texture so loose that it crumbles  
etween the fingers. The object of malting  
e this change: when it is accomplished,  
place when the acrospire has come nearly  
f the seed, the process is stopped by drying  
on the kiln. The temperature at first does  
00°; but it is raised very slowly up to 140°,  
according to circumstances. The malt is  
l, to separate the rootlets, which are consi-  
curious.

short sketch of the process of malting.  
being converted into malt, generally in-  
or three *per cent.* in bulk; and loses, at an  
out a fifth of its weight, or 20 *per cent.* But  
parts 12 are to be ascribed to kiln-drying,  
of water, which the barley would have lost  
exposed to the same temperature: so that  
does not exceed eight *per cent.* From a  
trials, made with as much attention to all  
stances as possible, the following seems to  
of accounting for this loss:

Loss sus-  
tained in  
malting,

ed off by the steep-water.....	1.5
pated in the floor.....	3.0
s, separated by cleaning.....	3.0
e.....	0.5
	<hr/>
	8.0

on the floor ought to be entirely owing to  
on of carbon by the oxygen of the atmo-  
t were this the only cause, it would be much

Book IV.

smaller than three *per cent.* Two other causes concur to produce this loss: 1. Many of the roots are broken off during the turning of the malt; these wither and are lost, while others grow in their place: 2. A certain portion of the seeds lose the power of germinating, by bruises or other accidents, and these lose a much greater portion than three *per cent.* of their real weight. From a good many trials, made with as much care as possible, I am disposed to conclude that the quantity of carbon, separated during the whole process of malting, by the formation of carbonic acid gas, does not exceed two *per cent.* and that the weight of the roots formed amounts often to four *per cent.* These two, in reality, include the whole real loss of weight which barley sustains when malted. What is lost in the steep, being husk, need scarcely be reckoned.

The roots appear, from the process, to be formed chiefly from the mucilaginous and glutinous parts of the kernel. The starch is not employed in their formation; but undergoes a change, intended no doubt to fit it for the future nourishment of the plumula. It acquires a sweetish taste, and the property of forming a transparent solution with hot water. In short, it approaches somewhat to the nature of sugar; but is much more soluble, and much more easily decomposed, than that principle. No doubt it is by the abstraction of carbon, which takes place on the malt floor, that this change is brought about. The action of hot water on barley meal seems gradually to induce a similar one.

Brewing.

2. Malt thus prepared is ground in a mill, and infused in a large cylindrical vessel, called the *mash-tun*, with somewhat more than its own bulk of water, of a temperature varying from  $160^{\circ}$  to  $180^{\circ}$ , according to

ty of the brewer. The infusion is left covered for three hours, and then the liquid drawn off at the bottom of the vessel. More hot water afterwards added, and the infusions repeated in a manner, till the malt is sufficiently exhausted.

The liquid thus obtained is called *wort*. It has a colour, a luscious sweet taste, a peculiar smell, and the process is properly conducted is perfectly pure. It consists of the water employed holding nearly part of the malt in solution. When examined by reagents, it appears to consist chiefly of four substances held in solution together: namely, 1. A sweet tasted substance, to which the name of *saccharine matter* has been given. It is by far the greatest point of quantity. This substance when separated has a light brown colour; when dried at 160°, it becomes a brittle mass with a glazed surface; at the temperature of 180°, or a little higher, its colour becomes darker; and if we keep it in that temperature, heating it occasionally, it becomes at last almost black, loses its sweet taste altogether, and acquires a disagreeable one. In a temperature somewhat below the boiling point, it is charred. It is soluble in water, and if once dissolved can scarcely be recovered again by evaporation without considerable loss. Alcohol dissolves it very imperfectly, and when heat is applied it deprives the alcohol of water, and forms a tough mass like turpentine, which refuses to dissolve. The specific gravity of this saccharine matter is 1.352. It appears to be an essential constituent of wort. 2. Starch. The presence of this substance is easily detected by dropping a solution of nutgalls into wort; a precipitate appears,

Constituents of wort.



## Book IV.

which is mostly redissolved by heating the liquid to  $120^{\circ}$ . 3. The insoluble part of the precipitate is a combination of gluten and tannin. The proportion of gluten in wort is very inconsiderable. That of the starch probably diminishes in proportion as the barley is more completely malted. I have detected starch in pretty old and perfectly transparent ale; but the gluten had disappeared. New ale, however, often contains traces of it. 4. The fourth ingredient in wort is *mucilage*, which precipitates in flakes when the wort is dropped into alcohol. Its quantity is more considerable in the worts last drawn off than in the first worts.

The wort is boiled with a quantity of hops, which vary considerably, but which may be stated in general at about  $\frac{1}{4}$ th of the weight of the malt. When sufficiently concentrated, it is thrown into very wide flat vessels called *coolers*, placed in the most open situation that can be had. Here it is cooled down to the temperature of about  $52^{\circ}$ , and then let down into a deep round wooden vessel called the *fermenting tun*. The specific gravity of the wort when put into the fermenting tuns varies very much. The wort of strong ale is sometimes as low as 1.070 (or perhaps even lower); sometimes as high as 1.127. In the first case it contains 16.6 *per cent.* of solid matter; in the second 28.9 *per cent.* The wort of small beer varies from 1.015 to 1.040; the first containing not quite 3.5 *per cent.* and the second about 9.5 *per cent.* of solid matter.

## Hops.

The use of the hops is partly to communicate a peculiar flavour, from the oil which they contain; partly to cover the sweetness of saccharine matter by the bitter principle which they contain; and partly to counteract the tendency which wort has to run into acidity.



If the wort be let down into the fermenting tun at a temperature of  $60^{\circ}$ , or rather higher, the substances which it holds in solution begin gradually to act upon each other, and to decompose each other. The temperature rises, an intestine motion takes place, a scum collects on the surface, and carbonic acid gas is emitted. This intestine motion is called *fermentation*. The position of wort to ferment is not sufficiently great to induce it with the requisite rapidity. It takes place slowly and imperfectly, that the liquor runs into acidity before the formation of ale has made sufficient progress. To prevent this, it is requisite to add to the wort some substance which has the property of inducing speedy fermentation. The substance made choice of is *yeast*, or the frothy matter which collects on the surface of the beer while fermenting. The quantity of yeast used by brewers is but small, generally about a gallon to every three barrels of the wort.

The yeast thus added appears to act chiefly upon the saccharine matter held in solution in the wort, to decompose it while it undergoes partial decomposition itself. By this mutual action the saccharine matter disappears, the specific gravity of the wort diminishes, and its properties alter, being converted into the intoxicating liquor called *ale*. During this mutual action the temperature of the liquid increases, and the increase depends upon the violence of the fermentation. In ale the rise of temperature is but small, amounting on an average to about  $15^{\circ}$ , because the quantity of yeast is small; but in the fermentation of wash, it often amounts to  $50^{\circ}$ , or even more in some cases.

Considerable exertions have been made by chemists, to ascertain the nature of the substance in yeast

Analysis of  
Yeast.

Book IV.

which produces this striking effect upon wort, and to discover it if possible in other substances. Westrumb examined the yeast of beer. From 15360 parts of it he obtained the following substances :

Potash.....	13
Carbonic acid.....	15
Acetic acid.....	10
Malic acid.....	45
Lime.....	60
Alcohol.....	240
Extractive.....	120
Mucilage .....	240
Saccharine matter ,...	315
Gluten ,.....	480
Water &.....	13525

---

 15142

Gluten its  
essential  
constituent.

Besides some traces of phosphoric acid and of silica<sup>\*</sup>. But it is obvious, that all these ingredients are not essential. From the experiments of Westrumb, it appears that when the yeast is filtered, a matter remains upon the filter which possesses the properties of gluten; that when this substance is separated the yeast loses the property of exciting fermentation, but recovers it again when the gluten is added. Hence it follows that this glutinous matter is the essential constituent of the yeast. When yeast is kept for some time in cylindrical glass vessels, a white substance not unlike curd separates, and swims upon the surface. If this substance be removed, the yeast loses the property of exciting fermentation.

---

<sup>\*</sup> Crell's *Annals*, 1796, i. 12.

substance possesses many of the properties of gluten, though it differs from it in others. Its colour is whiter; it has not the same elasticity; and its particles do not adhere with the same force. It dissolves readily in acids. I have little doubt that this is not of yeast which is the real ferment. It may be treated as gluten somewhat altered, and much more exposed to decomposition. It existed, no doubt, in the grain, but underwent considerable modifications in the process of malting; and probably others during the fermentation of the beer from which it separated.

A substance analogous to gluten is the real ferment, which appears also from the experiments of Fabroni, who published a Treatise on Wine-making in 1785, and gained the prize proposed by the Florence Academy.

By heating the juice of grapes, and passing it through a filter, he separated an adhesive matter which possessed the properties of gluten. The juice deprived of this substance refused to ferment, but it fermented again when the glutinous matter was again added. The observations of Thenard confirm those of Fabroni, and in the juices of all fruits examined, a substance similar to that described by Fabroni, and which, according to him, is absolutely the same with pure gluten.

This substance is insipid, does not change vegetable blues, is insoluble in water, loses  $\frac{1}{4}$ th of its weight when dried, and is decomposed like animal substances. When eight parts of it were distilled, they yielded 33 of charcoal, and yielded 1.61 of water, 1.31 of a quantity of ammonia, which, when saturated with muriatic acid, formed 1.46 of sal-ammoniac. The gas obtained weighed 0.33, and consisted of

Book IV.  $\frac{1}{2}$ th carbonic acid, and  $\frac{1}{2}$ ths of carbureted hydrogen, requiring  $1\frac{1}{2}$  times its bulk of oxygen to consume it. Nitric acid, even when diluted, converts it into a species of tallow. With potash it forms a soap, while ammonia is disengaged. When mixed with sugar and a sufficient quantity of water, fermentation takes place, carbonic acid is disengaged, and a vinous liquor formed. By this action the ferment loses the whole of its azote, and becomes incapable of exciting fermentation when mixed with a new portion of sugar \*.

The essential constituent of yeast, then, may be considered as a species of gluten, differing in several respects from the gluten of wheat. When mixed with the wort, this substance acts upon the saccharine matter: the temperature rises, carbonic acid is disengaged, and the saccharine matter is converted into ale. The yeast soon collects on the top of the liquid, but the brewer occasionally mixes it again to continue the fermentation. The quantity of yeast employed being small, the saccharine matter is but imperfectly decomposed. Ale. Hence a considerable portion of it still remains in the ale, and gives it that glutinousness and body for which it is remarkable. The specific gravity of ale varies very much according to the original strength of the wort, and the extent to which the fermentation has been carried. The limits may be stated at about 1.036 and 1.012.

The properties of ale are so well known that no description is deemed necessary. As it possesses intoxicating qualities, it has been considered as holding alco-

---

\* Thenard, *Ann. de Chim.* xvi. 302.



hol in solution; but this is by no means proved. It is true, that when distilled it yields alcohol; but this, as Berthollet has observed, may be in consequence of a decomposition brought about by the heat \*. It is certain that the intoxicating quality of ale is by no means proportional to the quantity of alcohol which it yields when distilled. Chap. IV.

## II. WASH.

ALE being intended as an article of food, and its value depending in a great measure on its flavour and appearance, particular attention is paid to obtain these in as great perfection as possible. But there is another species of ale which is brewed by the distillers for the express purpose of procuring from it ardent spirits by a subsequent process. The method which they follow is in several respects different. In particular, they endeavour to carry the fermentation to as great a length as possible, because the quantity of spirits is proportional to the saccharine matter decomposed, whatever remains unaltered yielding none. It is here, therefore, that the effects of fermentation can be best observed.

1. In this country the distillers do not brew from pure malt; they use chiefly raw grain. The proportion of malt varies from a third to a tenth part of the raw grain employed: This mixture they grind to meal, infuse with water at a heat considerably lower than that of the water used by the brewers, and employ much more agitation to mix it completely. The wort is drawn off and cooled Brewing.

\* *Statique Chimique*, ii. 528.

*Book IV.* in the usual way, and fresh water poured on to exhaust the grain.

The wort thus formed is not so transparent as that from malt, but its taste is nearly as sweet. It would appear, therefore, that the starch in the raw grain undergoes a certain change during the mashing, and is brought towards the state of saccharine matter.

In this country, where the duty is levied chiefly upon the *wash*\*, the distillers make the specific gravity of their wort as high as from 1.084 to 1.110: this they do not by boiling, but by *lobbing*; that is, by preparing a strong infusion of the flour of malt, or of barley and malt and hot water, and adding this almost saturated solution to the wort till it has acquired the requisite strength. But in Holland, where the duties are levied in a different way, the specific gravity of the wort is much lower.

Fermentation.

The wort thus made is let down into the fermenting tun at a temperature varying from 55° to 70°, according to the quantity, the season, the goodness of the yeast, and the skill of the distiller. Here it is mixed successively with considerable portions of the best yeast that can be procured, and the fermentation is urged as far as it can be made to go. The process lasts about ten days, and the temperature rises usually to between 90° and 100°, and sometimes even higher. Great quantities of carbonic acid are disengaged, and the liquid becomes specifically lighter; sometimes sinking to 1.000, and usually to from 1.007 to 1.002. The success of the fermentation is estimated by this loss of specific gravity.

---

\* This is the name given to the fermented wort of distillers.

The wash thus prepared is distilled. What comes over first is denominated *low wine*, and is concentrated by a second distillation.

Chap. IV.

This fermentation is obviously the consequence of the action of the peculiar ferment in yeast upon the saccharine matter of the wort. Even when the fermentation is carried to its greatest extent, it does not appear that the whole solid matter held in solution by the wort is decomposed. Nine trials were made upon the wort of pure malt; in all of them the fermentation went on pretty successfully, as may be seen from the following Table:

Always incomplete.

Specific gravity of the wort.	Specific gravity of the wash.
1.040 .....	1.0014
1.056 .....	1.0016
1.050 .....	1.000
1.0492 .....	1.0012
1.0465 .....	1.0045
1.045 .....	1.0047
1.0465 .....	1.0007
1.051 .....	1.0007
1.0524 .....	1.0004

When a portion of these different liquids was evaporated to dryness, the quantity of solid matter which it left was found to amount to  $\frac{1}{4}$ th, at an average, of the original quantity. Thus  $\frac{3}{4}$ ths had been decomposed by the fermentation, and  $\frac{1}{4}$ th still remained. This matter was still capable of fermentation, when redissolved in water and mixed with fresh yeast. On comparing the quantity of alcohol of 0.825, obtained in these trials, with the weight of solid matter of the malt which had been decomposed by the fermentation,

**Book IV.** the result was, that every pound weight of solid matter, so decomposed, furnished almost exactly half a pound of alcohol, of the specific gravity 0·825.

When sugar, dissolved in four times its weight of water, and mixed with yeast, is placed in the proper temperature, it ferments precisely as wort does, and yields the same products. It has been employed, therefore, by chemists as a less complicated means of ascertaining the phenomena of fermentation. Thenard mixed 60 parts of yeast with 300 of sugar, and fermented them in the temperature of 59°. In four or five days, he informs us, that all the saccharine matter had disappeared\*. The quantity of carbonic acid evolved amounted, by weight, to 94·6 parts. It was perfectly pure, being completely absorbed by water†. The fermented liquid, being distilled, yielded 171·5 parts of alcohol, of the specific gravity ·822. When the residue of the distillation was evaporated, 12 parts of a nauseous acid substance were obtained; and 40 parts of the yeast still remained; but, upon examination, it had lost the whole of its azote. This experiment gives us the following quantities:

1. *Substances fermented.*

Sugar.....	300
Yeast.....	60

---

360

\* There is reason to doubt the precision of this assertion, as it never happens in the great scale, where every thing is much more favourable.

† The very pungent aromatic odour which carbonic acid has when disengaged from the fermenting tun, shows that it contains a portion of the wash; and this has been verified by actual experiment.



2. *Products of fermentation.*

## Chap. IV.

Alcohol of .822 .....	171.5
Carbonic acid .....	94.6
Nauseous residue .....	12.0
Residual yeast .....	40.0
	<hr/>
Loss .....	318.1
	<hr/>
Loss .....	41.9

The loss here amounts to about a ninth part of the whole, and must either be ascribed to waste, or to the formation of water. The first is the more probable supposition. From this experiment, we learn that 100 parts of sugar, supposing the yeast not to furnish any thing, would yield,

Alcohol .....	57.16
Carbonic acid .....	31.53
Nauseous residue .....	4.00
	<hr/>
	92.69
Loss .....	7.31

Here the produce of alcohol is greater than that obtained from wort of barley; but the produce of carbonic acid is somewhat less. The well-known experiment of Lavoisier corresponds pretty well with the result obtained by Thenard. 100 pounds of sugar and 10 of yeast yielded,

Alcohol .....	57.70
Carbonic acid .....	35.34
Residue .....	6.59
	<hr/>
	99.63

These experiments are sufficient to show us, that by far the greatest part of the produce is obtained from

Book IV.

the sugar. The yeast acts chiefly by inducing the decomposition of that substance; but as it loses its azote, and in part disappears, we must allow it to furnish a portion of the new substances formed.

Seguin has endeavoured to prove that the essential constituent of yeast is not gluten, but albumen. It must be observed, however, that the nature of vegetable albumen is by no means well defined. Fabroni found that the albumen of eggs does not act as a ferment. It is clear that vegetable albumen differs exceedingly from animal; and I have no doubt that the same substance has been described by Thenard and Seguin under different names.

Whether an acid be necessary for fermentation.

Fabroni found that the gluten of wheat acted but imperfectly as a ferment; but that its efficacy was much improved by the addition of tartar. Berthollet repeated these experiments successfully. He ascribes the efficacy of tartar to the property which it has of promoting the solubility of the gluten. The presence of an acid was supposed formerly to be necessary for fermentation; but this does not seem to be the case. It is true, indeed, that an acid usually makes its appearance during fermentation. The formation of this acid has been ascribed to the action of the yeast upon the mucilaginous or starchy parts of the wort: but from the experiments of Fourcroy and Vauquelin, it appears that it always makes its appearance when wort is fermented without any yeast. In these trials they obtained only vinegar, and no alcohol. When the wort, either of raw grain or of malt, is fermented at the temperature of  $80^{\circ}$ , without any yeast, the gas which comes over consists of one-half carbonic acid and one-

all hydrogen; but at a lower temperature pure malt-  
wort does not yield any inflammable gas \*.

Chap. IV.

### III. WINE.

There is a considerable number of ripe fruits from which a sweet liquor may be expressed, having at the same time a certain degree of acidity. Of such fruits we have in this country the apple, the cherry, the gooseberry, the currant, &c. but by far the most valuable of these fruits is the *grape*, which grows luxuriantly in the southern parts of Europe. From grapes, fully ripe, may be expressed a liquid of a sweet taste, to which the name of *must* has been given. This liquid is composed almost entirely of five ingredients; namely, *water, sugar, jelly, gluten*, and *tartaric acid* partly saturated with *potash*. The quantity of sugar which grapes fully ripe contain is very considerable; it may be obtained in crystals by evaporating must to the consistence of syrup, separating the tartar which precipitates during the evaporation, and then setting the must aside for some months. The crystals of sugar are gradually formed. From a French pint of must, the Marquis de Lillion extracted half an ounce (French) of sugar, and an ounce of tartar †. According to Proust, the Muscadine grape contains about 30 per cent. of a peculiar species of sugar §.

Fruits af-  
fording  
wine.

Must.

When must is put into the temperature of about 70°, different ingredients begin to act upon each other, what is called *vinous fermentation* commences. The

Undergoes  
the vinous  
fermenta-  
tion.

\* *Ann. des Mus. d'Hist. Nat.* vii. 16.

† *Ann. Jour. de Phys.* xxi. 3.

‡ *Ibid.* p. 5.

§ *Ibid.* lvi. 173.



Book IV.

phenomena of this fermentation are an intestine motion in the liquid; it becomes thick and muddy, its temperature increases, and carbonic acid gas is evolved. In short, the very same changes take place as have been remarked when describing the fermentation of ale. In a few days the fermentation ceases, the thick part subsides to the bottom, or rises to the surface, the liquid becomes clear, it has lost its saccharine taste, and assumed a new one; its specific gravity is diminished; and it has become the liquid well known under the name of wine.

As this fermentation takes place without adding any ferment, it is obvious that the requisite substance is present in the juice. This substance was separated, and found by Fabroni to be analogous to the gluten of plants; and gluten being substituted for it, the fermentation succeeded. Fabroni has shown that the saccharine part of must resides in the cells of the grapes; while the glutinous matter, or ferment, is lodged on the membranes that separate the cells. Hence it follows, that in the fruit these two substances are not in contact. It is only after the juice is squeezed out that they are mixed. All other juices which undergo a spontaneous fermentation at the requisite temperature, have been shown by Thenard and Seguin to contain a similar substance. The formation of wine, then, is owing to the action of this glutinous matter on the saccharine substance of the juice, precisely as happens in the fermentation of ale.

All those juices of fruits which undergo the vinous fermentation, either with or without the addition of sugar, contain an acid. We have seen already in the First Chapter, that the vegetable acids are obtained chief,



n fruits. The apple, for instance, contains malic acid; the lemon, citric acid; the grape, tartaric and malic acids. The Marquis de Bullion has ascertained that must will not ferment if all the tartar which it contains is separated from it; but it ferments perfectly when restoring that salt \*. The same chemist ascertained that the strength of wine is considerably increased by adding tartar and sugar to the must †. We may infer from these facts, that the presence of a vegetable acid is of importance in these spontaneous fermentations.

It deserves attention, that Bullion obtained more tartar from verjuice than from wine; and he observed that the more the proportion of sugar in grapes increased, the more that of tartar diminished ‡.

It seems more than probable, from the experiments of Lavoisier and Chaptal, that the tartaric acid is partly decomposed during the fermentation, and that a portulacic acid is formed. The process, therefore, is more complicated than was suspected by Lavoisier. It is obviously analogous to combustion, as is evident from the evolution of caloric and the formation of carbonic acid, which is a product of combustion. Proust ascertained that, during the fermentation, not only carbonic acid, but azotic gas also, is disengaged. This demonstrates, that all the constituents of must are preserved; for sugar does not contain that principle §. Lavoisier could detect no azote in the carbonic acid from the fermentation.

When the fermentation has ceased, the liquor is put

*Ann. de Phys.* xxix. 4.—But the addition of salt of wood sorrel did not prevent the fermentation.

† *Ann. de Chim.* xxxvi. 26.

*Ann. de Phys.* xxix. 4.

‡ *Ibid.* lvi. 113.

*l. V.*

D d

See k IV.

into casks, where the remainder of the sugar is decomposed by a slow fermentation; after which the wine, decanted off the extractive matter, is put up in bottles.

Component  
parts of  
wine.

The properties of wine differ very much from each other, according to the nature of the grapes from which the must was extracted, and according to the manner in which the process was conducted. These differences are too well known to require a particular description. But all wines contain less or more of the following ingredients; not to mention water, which constitutes a very great proportion of every wine.

An acid,

1. *An acid*.—All wines give a red colour to paper stained with turnsole, and of course contain an acid. Chaptal has ascertained that the acid found in greatest abundance in wine is the malic, but he found them also of citric acid; and it is probable that wine is now entirely destitute of tartar. All wines which have the property of frothing when poured into a glass contain also carbonic acid, to which they owe their briskness. This is the case with champagne. These wines are usually weak; their fermentation proceeds slowly, and they are put up in close vessels before it be over. Hence they retain the last portions of carbonic acid that have been evolved.

Alcohol,

2. *Alcohol*.—All wine contains less or more of this principle, to which it is indebted for its strength; but in what particular state of combination it exists in wine cannot easily be ascertained. It is undoubtedly intimately combined with the other component parts of wine; as Fabroni has shown that it cannot be separated by saturating the wine with dry carbonate of potash, though a very small portion of alcohol, added

Chap. IV.

pose to wine, may be easily separated by means of salt. But if alcohol separates along with the carbonic acid during the fermentation, we can scarcely doubt that it has been formed. When wine is distilled, alcohol readily separates. The distillation is usually continued as long as the liquid which comes over is inflammable. The quantity obtained varies according to the wine, from a fourth to a fourteenth part of wine distilled. The spirit thus obtained is well known under the name of *brandy*. Bullion has observed, that when wine is distilled new it yields more alcohol than if it be allowed to get old \*. What remains after this distillation is distinguished in France under the name of *vinasse*. It consists of tartar, &c. and when evaporated to dryness, and subjected to combustion, yields potash.

*Extractive matter.*—This matter exists in all wines: but its proportion diminishes according to the age of the wine, as it gradually precipitates to the bottom.

Extract.

Every wine is distinguished by a peculiar flavour and odour, which probably depends upon the presence of a volatile oil, so small in quantity that it cannot be separated.

Oil,

The colouring matter of wine is originally contained in the husk of the grape, and is not dissolved till alcohol be developed. This matter is analogous to other colouring matters of plants: a set of bodies possessed of remarkable properties, but too little examined hitherto to be introduced with much advantage

And colouring matter.

\* Jour. de Phys. xxix. 6.

quart of	Highly rectified Spirit.			Thick, only, unctuous, resinous matter.			Gummy and tartarous matter.			Water.			
	oz.	dr.	gr.	oz.	dr.	gr.	oz.	dr.	gr.	lb.	oz.	dr.	gr.
and	1	6	00	3	2	00	1	5	00	2	5	3	00
ant	3	6	00	6	0	20	0	1	40	2	2	6	00
gundy	2	2	00	0	4	00	0	1	40	2	9	0	20
assone	2	6	00	0	4	10	0	1	20	2	8	4	30
mpagne	2	5	20	0	6	40	0	1	00	2	8	3	00
ch	3	0	00	0	6	40	0	1	00	2	8	0	20
tignac	3	0	00	3	4	00	0	5	20	2	4	6	30
Grave	2	0	00	0	6	00	0	2	00	2	9	0	00
nitage	2	7	00	1	2	00	0	1	40	2	7	5	20
cira	2	3	00	3	2	00	2	0	00	2	4	3	00
nsey	4	0	00	4	3	00	2	3	00	2	1	2	00
de	2	6	00	0	3	00	0	2	40	2	8	0	20
ate													
tiano	2	2	00	0	4	20	0	1	30	2	9	0	10
lle	3	0	00	2	4	00	1	0	00	2	5	4	00
adine	3	2	00	4	0	00	1	7	00	2	2	7	00
chatel	2	3	00	2	4	00	4	4	00	2	2	5	00
Sec	2	0	00	0	5	20	0	2	00	2	9	0	40
e	2	0	00	1	0	00	0	2	20	2	8	5	40
Chenish	2	2	00	0	3	20	0	1	34	2	9	1	06
ish	3	0	00	3	4	00	2	0	00	2	3	4	00
anca	3	0	00	6	0	00	2	2	00	2	0	6	00
y	1	2	00	2	4	00	9	4	00	1	10	6	00
ish	3	0	00	6	4	00	1	6	00	2	0	6	00
Tinto	2	2	00	4	3	00	5	0	00	2	0	3	00
ay	1	4	00	1	2	00	0	4	00	2	8	6	00
ol red	1	6	00	0	4	40	0	2	20	2	9	3	20
ne	2	0	00	0	7	00	0	3	00	2	7	0	00
l wine													
laite													

To this head belong not only common wine, but all  
 intoxicating liquors made from vegetable juices; as  
 cider from apples, perry from pears, currant wine, &c.



Book IV. likewise the liquor made from the juice of the sugar cane, the sugar mapple, &c.

---

### SECT. III.

#### OF THE ACETOUS FERMENTATIONS.

Wine fer-  
ments and  
becomes  
sour.

IF wine or beer be kept in a temperature between 70° and 90°, it gradually becomes thick, its temperature augments, filaments are seen moving through it in every direction, and a kind of hissing noise may be distinguished. These intestine motions gradually disappear, the filaments attach themselves to the sides and bottom of the vessel, and the liquor becomes transparent. But it has now lost its former properties, and is converted into acetous acid. This intestine decomposition has been long distinguished by the name of *acetous fermentation*, because its product is *acetic acid*. That this fermentation may take place, certain conditions must be attended to. The most important of these will appear from the following observations:

Alcohol not  
susceptible  
of this  
change.

1. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer is on which the experiment is made, the more readily is it converted into vinegar: the stronger they are they resist the change with the greater obstinacy. But it results from the experiments of Becher, that strong wines, &c. are made to undergo the acetous fermentation, & a much better and stronger vinegar than w

alcohol, though of itself it refuses to undergo the process, yet when other bodies are present which readily ferment, is decomposed during the process, and contributes to the formation of the acetic acid.

Wine, entirely deprived of glutinous matter either by spontaneous deposition or by clarification, does not undergo the acetous fermentation, unless some mucinous matter be mixed with it. Chaptal exposed wine destitute of this matter, in open bottles, to the hottest summer heat of Montpellier for 40 days, and it did not become sour: but upon adding some vinegar to the same wine, it became acid in a few days\*. When the water in which gluten of wheat has been allowed to ferment is mixed with sugar, the liquid is converted into vinegar without fermentation, without effervescence, and without the contact of air†. The cause of this curious change has not been explained.

Glutinous matter necessary.

Wine never becomes sour, provided it be completely deprived of all access to atmospheric air. The reason is, that during the acetous fermentation the oxygen of the atmosphere is partly converted into carbonic acid. It was supposed to have been absorbed; but the experiments of Saussure have shown that this is not the case. He found, that when wine was converted into vinegar in a given portion of air, the bulk was diminished; the quantity of carbonic acid just compensating the oxygen which had disappeared, except in as far as that carbonic acid was absorbed by the acid. The quantity of carbonic acid formed during

Carbonic acid formed.

\* *Ann. de Chim.* xxxvi. 245.

† Berthollet and Vauquelin, *Ann. de Mus. d'Hist. Nat.* vii. 4.

Book IV.

this conversion of wine into vinegar does not seem to be great; amounting, in Saussure's trials, to about twice the bulk of the wine \*. Hence the reason that wine or beer is apt to become sour after the cork has been drawn, and still more apt when part has been poured out of the bottle.

A certain temperature required.

4. A pretty high temperature is necessary for the commencement of the acetous fermentation. Wine or beer (unless very weak) scarcely becomes sour under the temperature of 65° or 70°. The fermentation is very apt to commence when the temperature suddenly rises. It is said, too, that wine and beer are more apt to become sour at certain seasons of the year than at others.

The vinegar-makers in this country keep their wash in stoves, heated to about the temperature of 90°, till the change is completed. From the experiments of Fourcroy and Vauquelin, it appears that vinegar made from grain holds in solution a quantity of gluten, and that a great part of it is separated by heating the vinegar boiling hot. This separation prevents the vinegar from being so apt to spoil.

Effects of the fermentation.

5. When the acetous fermentation is completed, the whole of the malic acid originally contained in the wine has disappeared as well as the alcohol. We must conclude, therefore, that they have been both converted into acetic acid. Part of the glutinous matter has also undergone the same change, and seems indeed to have been the substance that first began the change. Part of it is deposited in the state of flakes; part remains in

---

\* *Recherches Chimique sur la Végétation*, p. 144.

solution, and disposes the vinegar to decomposition. Vinegar also contains a little tartar, and probably also citric acid. Malic acid is also found in new vinegar; a proof that this part of the wine is the last to undergo the acetous fermentation.

6. From the late experiments of Cadet it appears, that sugar is the essential constituent in liquors to be converted into vinegar, and that the quantity of vinegar formed is proportional to the sugar. But if the sugar exceed an eighth part of the liquid, the whole is not decomposed. 7 water, 1 sugar, and some yeast, ferment in a proper temperature, and form an excellent vinegar \*.

7. Acetic acid is formed in many other cases of the decomposition of vegetables besides the acetous fermentation. These have been pointed out with much ingenuity by Vauquelin and Fourcroy. They may be reduced under three heads. *First*, When sugar, gum, tartar, wood, &c. are distilled in a retort, or even burnt in the open fire, acetic acid separates in combination with an empyreumatic oil, which gives it a peculiar odour. Hence it was mistaken for other acids, and distinguished by the names of *pyromucous*, *pyrolignous*, *pyrotartarous acids*, till its real name was ascertained by these distinguished chemists †. *Secondly*, When concentrated sulphuric acid is poured upon the same vegetable bodies, they are decomposed in a very different manner; being converted into water, charcoal, and acetic acid. *Thirdly*, Acetic acid is evolved in considerable quantity during the spontaneous decomposition of urine and some

Acetic acid  
formed by  
other pro-  
cesses.

\* *Ann. de Chim.* lxi. 248.

† *Ibid.* xxxv. 83.



Book IV. other animal substances. Thus it appears that the component parts of acetic acid are extremely apt to combine together in those proportions which constitute that important acid.

---

#### SECT. IV.

##### OF PUTREFACTION.

Nature of  
putrefac-  
tion.

ALL vegetable substances, both complete plants and their component parts separately, when left entirely to themselves, are gradually decomposed and destroyed, provided moisture be present, and the temperature be not much under  $45^{\circ}$ , nor too high to evaporate suddenly all the moisture. This decomposition has obtained the name of *putrefaction*.

It proceeds with most rapidity in the open air; but the contact of air is not absolutely necessary. Water is in all cases essential to the process, and therefore is most probably decomposed.

Putrefaction is constantly attended with a fetid odour, owing to the emission of certain gaseous matters, which differ according to the putrefying substance. Some vegetable substances, as gluten and cruciform plants, emit ammonia; others, as onions, seem to emit phosphureted hydrogen gas. Carbonic acid gas and hydrogen gas, impregnated with unknown vegetable matters, are almost constantly emitted in abundance. From the experiments of Saussure, we learn, that when moist wood is left exposed to the air, a portion of the oxygen of the

osphere is converted into carbonic acid; for the quantity of this acid formed is just equal to the bulk of the oxygen which disappears. When the experiment is made under receivers, no other gas can be detected except carbonic acid; but in the open air the wood loses a much greater proportion of its weight than can be accounted for by the carbon thus abstracted.

This he ascribes to the escape of oxygen and hydrogen under the form of water. Hence the quantity of carbon in a given weight of rotten wood is greater than in the same weight of fresh; but when the putrefaction goes on in water without the contact of air, the wood becomes white and light, and contains a smaller portion of carbon than when fresh\*. The nature of the constituents of vegetable mould, as far as known, has been detailed in the preceding Chapter. Our chemical knowledge of vegetable compounds is still by far too limited to enable us to follow this very complicated process of putrefaction with any chance of success.

---

\* *Recherches Chimiques sur la Végétation.*

## BOOK V.

---

OF

## ANIMALS.

---

Book V.  
Animals  
and vegeta-  
bles

WHEN we compare animals and vegetables together, each in their most perfect state, nothing can be easier than to distinguish them. The plant is confined to a particular spot, and exhibits no mark of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

Not easily  
distinguish-  
ed.

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task: but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the

most perfect classes, and consequently are in no danger of being confounded with plants. Indeed, the greater number of facts which I have to relate apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

This part of the subject naturally divides itself into four Chapters. In the First Chapter, I shall give an account of the different ingredients hitherto found in animals, such of them at least as have been examined with any degree of accuracy: in the Second, I shall treat of the different members of which animal bodies are composed; which must consist each of various combinations of the ingredients described in the First Chapter: in the Third, I shall treat of those animal functions which may be elucidated by chemistry: and, in the Fourth, of the changes which animal bodies undergo after death.



eparated, be washed repeatedly in cold water till the liquid ceases to be coloured, or to abstract any thing ; the skin, thus purified, be put into a quantity of pure water, and boiled for some time, part of it will be dissolved. Let the decoction be slowly evaporated till it is reduced to a small quantity, and then put aside to cool. When cold, it will be found to have assumed a solid form, and to resemble precisely that tremulous substance well known to every body under the name of *jelly*. This is the substance called in chemistry *gelatine*. If the evaporation be still farther continued, by exposing the jelly to dry air, it becomes hard, semitransparent, breaks with a glassy fracture, and is in short the substance so much employed in different arts under the name of *glue*. Gelatine, then, is precisely the same with glue ; only that it must be supposed always free from those impurities with which glue is so often contaminated.

2. Gelatine is semitransparent and colourless when pure. Its consistency and hardness vary considerably. The best kinds are very hard, brittle, and break with a glassy fracture. Its taste is insipid, and it has no smell.

Properties.

When thrown into water it swells very much, but does not readily dissolve ; and when taken out, it is soft and gelatinous ; but when allowed to dry, it recovers its former appearance. If it be put in this gelatinous state into warm water, it very soon dissolves, and forms a solution of an opal colour, and the more opaque according to the quantity of gelatine which it contains. Tremulous gelatine dissolves in a very small portion of hot water ; but as the solution cools, it gelatinizes afresh. If this solution, as soon as it assumes

nitric acid dissolves glue with great ease. The solution is of a brown colour, and still continues strong. It gradually lets fall a white powder. This powder precipitates tan in great abundance from water, and may be employed with advantage to detect when an alkali conceals it. Sulphuric acid acts more slowly. The solution is brown, and gradually deepens; sulphurous acid is exhaled during the action of sulphuric acid on glue. Neither sulphuric nor nitric acid occasion any change in the solution when in water.

When a current of oxymuriatic acid gas is passed through a solution of gelatine in water, a white solid matter collects on the surface, and whitish filaments pass through the liquid. This solid matter, when separated by the filter and purified, possesses the following properties: Its colour is white; it is specifically lighter than water; it has little or no taste; when dried in open air it falls to powder; it is not soluble in water; it dissolves in hot nitric and acetic acids, and precipitates again as the solution cools; when treated with potash it emits the smell of ammonia; it does not affect vegetable blues\*. Bouillon La Grange, from whom we are indebted for these facts, has given the name thus altered the name of *oxygenized gelatine*.

Alkalies dissolve gelatine with facility, especially when assisted by heat; but the solution does not possess the properties of soap.

Of alkalies  
and earths,

None of the earths seem to combine with gelatine; and they do not precipitate it from its solution in

\* Bouillon La Grange, Nicholson's *Jour.* xiii. 209.

Book V.

water. The following Table exhibits the effect of different earthy solutions when mixed with a pretty concentrated solution of common glue.

SUBSTANCES.	EFFECTS.
Lime water	No change
Strontian water	No change
Barytes water	Became milky. Precipitate dissolved by acetic acid
Muriate of barytes	The same as the last
Silicated potash	No change
Aluminated potash	No change
Oxalate of ammonia	Became milky
Phosphate of soda	Became slightly milky

The milkiess produced by some of these reagents was not owing to their effect upon the gelatine, but upon the lime and the sulphuric acid which it contained.

Of the metallic oxides,

The metals in their pure state have no effect upon gelatine; but several of the metallic oxides, when agitated in a solution of gelatine, have the property of depriving the water of the greatest part of that body, with which they form an insoluble compound. Several of the metallic salts likewise precipitate gelatine from water. The following Table exhibits the result of mixing various metallic salts with a concentrated solution of gelatine, as far as my experiments have gone:

IC SOLUTIONS.	EFFECTS.
ariate of gold	A copious yellowish white precipitate. Soluble by adding water
of silver	Becomes slightly milky
of mercury	A very copious curdy precipitate
iate of mercury*	A copious white precipitate
ysulph. of mere.	No change
ysulph. of mere.	Cryst. become yellow, white flakes appear, and the liquid becomes transparent
e of mercury	No change
ate of copper	No change
of copper	Becomes milky
hate of copper	No change
of ammonia	No change
of iron †	A few yellow flakes appear
hate of iron †	Becomes slightly milky, as when alcohol is added
ate of iron	Assumes a pink colour
iate of iron	Becomes green
ariate of tin §	No change
iate of tin	Becomes slowly milky

stock, in his excellent paper on animal fluids, informs us, that one part of isinglass in 100 parts of water is not affected by the action of mercury. The result of my experiments with commercial isinglass was different; probably owing to the impurity of that substance.

in the state of oxy sulphate.

† Dissolved in alcohol.

acres of acid.

E e 2



Book V.

METALLIC SOLUTIONS.	EFFECTS.
Nitrate of lead Acetate of lead Plumbate of potash Plumbate of lime	No change
Muriate of zinc	No change
Muriate of antimony Tartar emetic	A copious flaky precipitate No change
Nitrate of bismuth precipitable by water Ditto not precipitable by water	Becomes milky No change
Muriate of arsenic	No change

Of alcohol. Gelatine is insoluble in alcohol. When alcohol is mixed with a solution of gelatine, the mixture becomes milky; but becomes again transparent when agitated, unless the solution be concentrated, and the quantity of alcohol considerable. Gelatine is most probably equally insoluble in ether; though I believe the experiment has not been tried.

Of tannin. When the solution of tannin is dropt into gelatine, a copious white precipitate appears, which soon forms an elastic adhesive mass not unlike vegetable gluten. This precipitate is composed of gelatine and tannin; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrefaction. It resembles exactly overtanned leather. The precipitate is soluble in the solution of gelatine, as Mr Davy first observed. Neither is the

can be thrown down, unless the solutions both of tannin and gelatine be somewhat concentrated. Tremula, as was first observed by the same chemist, does not precipitate tannin; but if we employ a solution of gelatine so strong that it gelatinizes when cold, and heated till it becomes quite liquid, it answers best for throwing down tannin. It is by this property of forming a white precipitate with tannin that gelatine is easily detected in animal fluids. It is not, however, a very decisive test, as *albumen* is also thrown down by tannin. Dr Bostock has pointed out a very accurate method of detecting and ascertaining the quantity of gelatine contained in an animal fluid. If oxygen of mercury produce no precipitate, we may be assured of the absence of albumen. Then the infusion of galls being mixed with the liquid, in such a proportion that the filtered liquid will neither precipitate infusions of galls, or the animal liquid under examination, a precipitate falls, composed of about two parts tannin and three parts gelatine. Hence this precipitate dried in a water bath, and multiplied by 0.6, gives us the quantity of gelatine in the liquid examined very nearly. Gelatine does not, properly speaking, combine with water, but it renders them miscible with water, and forms an emulsion.

From the effects of different reagents on gelatine, and from the decomposition which it undergoes when

Composition.

stock, Nicholson's *Jour.* xiv. 144. From the latter experiments, it appears that the compound of tannin and gelatine differs in the proportion of its constituents according to circumstances. It does, therefore, furnish us with a method of detecting the quantity of gelatine in a solution. Nicholson's *Jour.* xxi. 1.

Book V. heated, we see that it contains carbon, hydrogen, azote, and oxygen. But what the proportion of these constituents are, cannot be easily ascertained. The phosphate of lime, and the traces of soda, which it always yields, are most likely only held in solution by it.

Species. 5. Gelatine, like all other constituents of animal bodies, is susceptible of numerous shades of variations in its properties; and of course is divisible into an indefinite number of species. Several of these have been long known and manufactured for different purposes; and many curious varieties have been pointed out by Hatchett in his admirable *Dissertations on Shell, Bone, and Zoöphytes*, published in the *Philosophical Transactions* for 1797 and 1800. The most important species are the following:

Glue. 1. *Glue*. This well-known substance has been long manufactured in most countries, and employed to cement pieces of wood together. It is extracted by water from animal substances, and differs in its qualities according to the substances employed. Bones, muscles, tendons, ligaments, membranes, and skins, all yield it; but the quality is best when skins are employed; and those of old animals yield a much stronger glue than those of young animals. English glue is considered as the best, owing to the care with which it is made. The parings of hides, pelts from furriers, the hoofs and ears of horses, oxen, calves, sheep, &c. are the substances from which it is extracted in Britain, and quantities of these substances are imported for the purpose. They are first digested in lime-water to clean them, then steeped in clean water, laid in a heap till the water runs off, and then boiled in brass caldrons with pure water. The impurities are skimmed off as they rise.



and when the whole is dissolved, a little alum or finely powdered lime is thrown in. The skimming having been continued for some time, the whole is strained through baskets, and allowed to settle. The clear liquid is gently poured back into the kettle, boiled a second time, and skimmed till it is reduced to the proper consistency. It is then poured into large frames, where it concretes on cooling into a jelly. It is cut by a spade into square cakes, which are again cut by means of a wire into thin slices; these slices are put into a kind of coarse net work, and dried in the open air. The best glue is extremely hard and brittle; it has a dark brown colour, and an equal degree of transparency without black spots. When put into cold water, it swells very much, and becomes gelatinous, but does not dissolve. When glue is soluble in cold water, it is a proof that it wants strength. Dry glue, according to Dr Bostock, contains  $10\frac{1}{2}$  per cent. of water. He thinks also that it contains albumen. But from the method of preparing it this can hardly be supposed†.

2. *Size*. This substance differs from glue in being colourless and more transparent. It is manufactured in the same way, but with more care; eel skins, vellum, parchment, some kinds of white leather, and the skins of horses, cats, rabbits, are the substances from which it is procured. It is commonly inferior to glue in strength. It is employed by paper-makers to give strength to that article, and likewise by linen manufacturers, gilders, polishers, painters, &c. &c.

\* Clennel. See Johnson's *History of Animal Chemistry*, i. 315.

† Nicholson's *Jour.* xxiv. 7.

‡ Clennel. See Johnson's *History of Animal Chemistry*, i. 315.



Book V.  
Isinglass.

3. *Isinglass*. This substance agrees with size in being transparent, but it is much finer, and is therefore sometimes employed as an article of food. It is prepared in Russia from the air-bladders and sounds of different kinds of fish which occur in the mouths of large rivers; chiefly different species of *accipenser*, as the *sturio stellatus*, *buso ruthenus*, and likewise the *sibiricus glanis*. The bladder is taken from the fish, clean washed, the exterior membrane separated, cut lengthwise and formed into rolls, and then dried in the open air. When good, isinglass is of a white colour, semitransparent, and dry. It dissolves in water with more difficulty than glue, probably because it is not formed originally by solution. From the analysis of isinglass by Hatchett, we learn that it is almost completely convertible into gelatine by solution and boiling. 500 grains of it left by incineration 1.5 grains of phosphate of soda, mixed with a little phosphate of lime.

A coarse kind of isinglass is prepared from sea wolves, porpoises, sharks, cuttle fish, whales, and all fish without scales. The head, tail, fins, &c. of these are boiled in water, the liquid skimmed and filtered, and then concentrated by evaporation till it gelatinizes on cooling. At that degree of concentration it is cast on flat slabs and cut into tablets. This species is used for clarifying, stiffening silk, making sticking plaster, and other purposes\*.

Substances  
containing  
it.

6. Gelatine exists in great abundance in animals, forming a constituent part both of their fluid and solid

---

\* Fabricius de *Ichthyocolla*. Jackson on *British Isinglass*, *Phil. Trans.* 1788, and Johnson's *Animal Chemistry*, i. 231.

parts. Blood and milk yield it always; and it makes its appearance occasionally in the other liquids. It forms an essential part of bones, ligaments, tendons, membranes, skin, muscles, hair, &c. Chap. I.

7. Its uses are very numerous. In the state of jelly it constitutes one of the most nourishing and palatable species of food. It constitutes the basis of soups. The great variety of purposes to which it is applied in the state of glue, size, and isinglass, are well known. Uses.

## SECT. II.

### OF ALBUMEN.

THE eggs of fowls contain two very different substances: a yellow oily-like matter, called the *yolk*; and a colourless glossy viscid liquid, distinguished by the name of *white*. This last is the substance which chemists have agreed to denominate *albumen*\*. The white of an egg, however, is not pure albumen. It contains also some mucus, soda, and sulphur: but as albumen is never found perfectly pure, and as no method is known of separating it without at the same time altering the properties of the albumen, chemists are obliged to examine it while in combination with these bodies. Contained in eggs.

---

\* This is merely the Latin term for the white of an egg. It was first introduced into chemistry by the physiologists.

Book V.

Coagulates  
when heat-  
ed.

Albumen dissolves readily in water, and the solution has the property of giving a green colour to vegetable blues, in consequence of the soda which it contains. When albumen is heated to the temperature of  $165^{\circ}$ , it *coagulates* into a white solid mass; the consistency of which, when other things are equal, depends, in some measure, on the time during which the heat was applied. The coagulated mass has precisely the same weight that it had while fluid. This property of coagulating when heated is characteristic of albumen, and distinguishes it from other bodies.

The taste of coagulated albumen is quite different from that of liquid albumen: its appearance, too, and its properties, are entirely changed; for it is no longer soluble, as before, either in hot or in cold water.

The coagulation of albumen takes place even though air be completely excluded; and even when air is present there is no absorption of it, nor does albumen in coagulating change its volume †. Acids have the property of coagulating albumen, as Scheele ascertained ‡. Alcohol also produces, in some measure, the same effect. Heat, then, acids and alcohol, are the agents which may be employed to coagulate albumen.

It is remarkable, that if albumen be diluted with a sufficient quantity of water, it can no longer be coagulated by any of these agents. Scheele mixed the white of an egg with ten times its weight of water, and then, though he even *boiled* the liquid, no coagulum appeared. Acids, indeed, and alcohol, even then coagulated

\* Cullen.

† Carradori, *Ann. de Chim.* xlix. 98.

‡ Scheele, ii. 58.



t; but they also lose their power if the albumen be diluted with a much greater quantity of water, as has been ascertained by many experiments. Now, when water is poured into albumen, its integrant particles must be farther separated from each other, and their distance must increase with the quantity of water with which they are diluted. We see, therefore, that albumen ceases to coagulate whenever its particles are separated from each other beyond a certain distance. That no other change is produced, appears evident from this circumstance, that whenever the watery solution of albumen is sufficiently concentrated by evaporation, coagulation takes place, upon the application of the proper agents, precisely as formerly.

It does not appear that the distance of the particles of albumen is changed by coagulation; for coagulated albumen occupies precisely the same sensible space as liquid albumen\*.

Now, to what is the coagulation of albumen owing? We can conceive no change to take place from a state of liquidity to that of solidity, without some change in the figure of the particles of the body which has undergone that change. Now such a change may take place three ways: 1. The figure may be changed by the addition of some new molecules to each of the molecules of the body. 2. Some molecules may be abstracted from every integrant particle of the body. 3. Or the molecules, of which the integrant particles are composed, may enter into new combinations, and form new integrant particles, whose form is different from that of

Inquiry  
into the  
cause.

\* Carraderi.



Book V.

the old integrant particles. Some one or other of these three things must take place during the coagulation of albumen.

1. Scheele and Fourcroy have ascribed the coagulation of albumen to the first of these causes, namely, to the addition of a new substance. According to Scheele, *caloric* is the substance which is added. Fourcroy, on the contrary, affirms that it is *oxygen*.

Ascribed  
to caloric ;

Scheele supported his opinion with that wonderful ingenuity which shone so eminently in every thing which he did. He mixed together one part of white of egg and four parts of water, added a little pure alkali, and then dropt in as much muriatic acid as was sufficient to saturate the alkali. The albumen coagulated. But when he repeated the experiment, and used carbonate of alkali instead of pure alkali, no coagulation ensued. In the first case, says he, there was a double decomposition: the muriatic acid separated from a quantity of caloric with which it was combined, and united with the alkali; while, at the same instant, the caloric of the acid united with the albumen, and caused it to coagulate. The same combination could not take place when the alkaline carbonate was used, because the carbonic acid gas carried off the caloric, for which it has a strong affinity\*.

To oxygen.

Fourcroy observes, in support of his opinion, that the white of an egg is not at first capable of forming a hard coagulum, and that it only acquires that property by exposure to the atmosphere. It is well known that the white of a new laid egg is milky after boiling; and

---

\* Scheele, ii. 38.

he shell be covered over with grease to exclude external air, it continues long in that state; whereas the white of an old egg, which has not been preserved in this manner, forms a very hard tough coagulum. Experiments are undoubted; and they render it exceedingly probable, that albumen acquires the property of forming a hard coagulum only by absorbing oxygen: they by no means prove that coagulation itself is effected by such an absorption. And since coagulation takes place without the presence of air, and since no oxygen when it is present, is absorbed, this opinion may be maintained without inconsistency.

The only substance which can be supposed to be absorbed by albumen during coagulation, since it does not lose weight, is *caloric*. We know that in most cases when a fluid is converted into a solid, caloric is actually disengaged. It is extremely probable, then, that here the disengagement takes place. But this has not been confirmed by any proof. Fourcroy says, that in an experiment made by him, the thermometer rose a great number of degrees. But no other person has ever been able to observe any such thing, it cannot be doubted that this philosopher was misled by some circumstance or other to which he did not attend\*.

The coagulation of albumen resembles exactly what takes place when concentrated silicated potash is saturated with muriatic acid. The mass slowly assumes an opal colour, and at last concretes into a solid mass. Now this jelly consists of the particles

---

\* Thomson's *Fourcroy*, iii. 271.

Book V.

of silica combined with each other, and with a certain portion of water. These particles were formerly held in solution by the potash; that is to say, the affinity of silica for potash was superior to the cohesive force which exists between the particles of silica. The muriatic acid, by saturating the potash, diminished the force of its affinity for the silica. The cohesive force of the silica, now superior, causes it to combine in masses, consisting of a certain portion of silica and water. These masses, equally diffused through the liquid, and at such small intervals as to cohere together, gives the whole a gelatinous form. Something like this seems to take place with respect to the albumen. Its particles, combined with water and also with soda, are all kept at equal distances in the liquid; because this affinity just balances their cohesive force. But when heat is applied, this affinity is diminished by the additional elasticity, or tendency to separate, given to the water and the soda. The cohesion of the albumen, now superior, causes its particles to combine in sets, forming solid bodies, equally distant from each other, and cohering together. Hence the gelatinous form, and the solidity of the coagulum, always inversely proportional to the quantity of water present. Thus it appears, that whatever diminishes the affinity between the water and soda and the albumen, occasions its coagulation, by allowing its cohesive force to act.

Albumen, then, is capable of existing in two states; the one before it has been coagulated, and the other after it has undergone coagulation. Its properties are very different in each. It will be proper therefore to consider them separately.

1. Albumen in its natural state, or uncoagulated, is a



glary liquid, having little taste and no smell. When dried spontaneously, or in a low heat, it becomes a brittle transparent glassy like substance; which, when spread thin upon surfaces, forms a varnish, and is accordingly employed by bookbinders for that purpose. When thus dried it has a considerable resemblance to gum arabic, to which also its taste is similar. The white of an egg loses about  $\frac{1}{4}$ th of its weight in drying. It is still soluble in water, and forms the same glary liquid as before.

Chap. I.  
Uncoagu-  
lated albu-  
men.

From the experiments of Dr Bostock, it appears, that when one part of this dry albumen is dissolved in nine parts of water, the solution becomes perfectly solid when coagulated by heat; but if the albumen amounts only to  $\frac{1}{11}$ th of the liquid, then, though coagulation takes place, the liquid does not become perfectly solid, but may be poured from one vessel to another\*.

When one grain of albumen is dissolved in 1000 grains of water, the solution becomes cloudy when heated†.

Uncoagulated albumen soon putrefies unless it be dried; in which state it does not undergo any change. It putrefies more readily when dissolved in a large quantity of water than when concentrated. The smell of white of egg, allowed to run into putrefaction, resembles that of pus‡.

Its proper-  
ties.

It is insoluble in alcohol and ether, which immediately coagulate it, unless it be mixed with a very great proportion of water; in which case even acids have no effect.

\* Nicholson's Jour. xiv. 141.      † Bostock, Ibid. xi. 247.

‡ Id. Ibid. xiv. 143.



# ANIMAL SUBSTANCES.

When acids are poured upon it, coagulation takes place equally; but several of them have the property of dissolving it again when assisted by heat. This at least is the case with sulphuric acid. The solution is of a green colour, and does not soon blacken even when boiled. It is the case also with nitric acid, and probably also with muriatic acid. Nitric acid first disengages some azotic gas; then the albumen is gradually dissolved, nitrous gas emitted, oxalic and malic acids formed, and a thick oily matter makes its appearance on the surface \*.

I tried the effect of different acids upon a solution consisting of the albumen of a common-sized hen's egg in about a pint of water, and filtered. The results may be seen in the following Table :

ACIDS.	EFFECTS.
1. Sulphuric acid .....	A white coagulum, which appears at the bottom first
2. Muriatic acid.....	Becomes at once very milky, flakes fall slowly
3. Nitric acid.....	A very copious precipitate of yellow flakes soon falls to the bottom, and a slight effervescence is perceptible
4. Oxymuriatic acid ...	Assumes a beautiful white colour, and fine white flakes slowly separate
5. Sulphurous acid.....	No change †. Coagulates in 12 hours
6. A weak fluoric acid	No change
7. Acetic acid .....	No change
8. Distilled vinegar ....	No change

\* Scheele, *Crell's Annals*, ii. 17. Eng. Transl.

† The water was saturated with the acid.

It is proper to mention, that the solution was made by alcohol but not by heat.

Chap. L

When alkalies are mixed with the solution of albumen in water, no apparent change takes place; but if a saturated solution of pure potash be triturated with it for some time, and then allowed to remain at rest, the albumen gradually coagulates or rather gels, for the coagulum has a striking resemblance to gelatin. It gradually hardens; and at a particular period of drying it resembles very exactly the lense of the microscope. When quite dry it is brittle and transparent.

Of alkalies  
and earths.

Effect of the different earthy bodies on the solution of albumen in water may be seen from the following Table. The solution consisted of one white of egg dissolved in about a pint of water, and filtered to remove the opaque white films which are always mixed with the white of egg.

SUBSTANCES.	EFFECTS.
Distilled water	No change
Rain water	No change
Spring water	No change
Sulphate of magnesia	No change
Carbonate of magnesia	No change
Saturated potash	No change
Diluted potash	No change

It appears that none of the earths form insoluble compounds with albumen; in this respect they differ from the alkalies.

Its use is very different with the metallic oxides. The following Table exhibits the effects of the metallic oxides on the same solution of albumen, as far as my experiments go.

Of metallic

Book V.

METALLIC SALTS.	EFFECTS.
1. Nitromuriate of gold	A copious yellow flaky precipitate, redissolved by ammonia *
2. Muriate of platinum	A yellowish-white precipitate
3. Nitrate of silver	A copious reddish-brown precipitate, not redissolved by ammonia
4. Nitrate of mercury	A white precipitate
5. Corrosive sublimate	A light white precipitate
6. Superoxy sulph. of do.	A white precipitate
7. Prussiate of do.	No change
8. Oxynitrate of copper	A green coagulum, redissolved by adding more of the copper; then the mixture becomes opaque
9. Muriate of copper	A copious white precipitate
10. Oxysulphate of copper	A greenish-white precipitate
11. Cuprate of ammonia	No change. Muriatic acid renders the mixture colourless, but no precipitate falls
12. Sulphate of iron	Brown flakes precipitate
13. Oxysulphate of ditto in alcohol	A copious dirty white precipitate
14. Oxymuriate of iron	No change
15. Oxynitrate of iron	No precipitate. Becomes green
16. Oxymuriate of tin	Becomes slowly milky

\* The salt had a slight excess of acid.



METALLIC SALTS.	EFFECTS.
17. Hyperoxymuriate of lead	A copious white precipitate
18. Acetate of lead	The same
19. Nitrate of lead	The same
20. Plumbate of potash	No change; but muriatic acid throws down a copious white precipitate
21. Plumbate of lime	No change
22. Muriate of zinc	Becomes slowly very milky
23. Nitrate of bismuth	A white precipitate, which does not appear immediately unless there be an excess of acid
24. Nitrate of antimony	A white precipitate
25. Muriate of arsenic	Becomes slowly milky
26. Arseniate of potash	No change
27. Arseniate of cobalt	No change
28. Prussiate of potash	No change
29. Oxalate of ammonia	A slight white precipitate appears after standing an hour

Thus we see that every metal tried, except cobalt, occasioned a precipitate; but no precipitate ever appeared when the oxide was held in solution by an alkali or earth. The effect of the metallic salts on albumen forms a striking contrast with their effect on gelatine.

From the experiments of Dr Bostock, it appears that a drop of the saturated solution of oxymuriate of mercury, let fall into water containing  $\frac{1}{1000}$ th part of its



ceptible of decomposition as uncoagulated albumen. Mr Hatchett kept it for a month under water, it did not become putrid. It is to the experience of this ingenious chemist that we are indebted for every thing at present known relative to coagulated albumen. By drying it in the temperature of 212° it is converted into a brittle hard yellow sub-transparent like horn\*.

Chap. I.  
Its properties.

When this substance was digested for some hours in water it gradually softened, and became white and like newly coagulated albumen. When water was allowed to act upon it long, a small portion of it is taken up, the watery liquid is not precipitated by the infusion of tan; but nitromuriate of tin occasions a faint

Action of water,

precipitate. According to Scheele, the mineral acids, when greatly diluted with water, dissolve a portion of coagulated albumen, which is thrown down again by the same acids concentrated †.

Of acids.

When coagulated albumen is steeped in diluted nitric acid, the acid in about four weeks begins to acquire a yellow tinge, which becomes gradually deeper; but the albumen, though it becomes more opaque, is not dissolved. The yellow acid, when saturated with ammonia, becomes of a deep orange colour, but does not precipitate. When the albumen, thus treated, is immersed in ammonia, the liquid assumes a deep blue colour, inclining to blood red. The albumen is dissolved, and the solution has a deep yellowish colour. If the albumen, after being steeped in

Changed into gelatine.

Hatchett, *Phil. Trans.* 1800.  
*ibid.*, ii. 57.

† Hatchett, *ibid.*

Book V.

nitric acid, be washed and then boiled in water, it is dissolved, and forms a pale yellow liquid, which gelatinizes when properly concentrated. If the gelatinous mass be again dissolved in boiling water, the solution is precipitated by tan and by nitro-muriate of tin. Hence we see that nitric acid has the property of converting coagulated albumen into gelatine. For this important fact we are indebted entirely to Mr Hatchett \*.

Concentrated nitric acid dissolves coagulated albumen with effervescence, especially when assisted by heat. It becomes orange brown when mixed with ammonia, but no precipitate falls †.

Action of  
alkalies.

It is readily dissolved by a boiling lixivium of potash, ammonia is disengaged, and an animal soap is formed. This soap, when dissolved in water, and mixed with acetic or muriatic acids, lets fall a precipitate which is of a saponaceous nature. When heated gently some oil flows from it, and a brownish viscid substance remains ‡. The alkalies, when diluted, and not assisted by heat, act upon it slowly and imperfectly.

These properties indicate sufficiently that coagulated albumen is a very different substance from uncoagulated albumen. During the coagulation its component parts must arrange themselves differently.

Composi-  
tion of al-  
bumen.

III. From the effects of nitric acid on albumen; and its products, when subjected to destructive distillation, it has been concluded that it consists of carbon, hydrogen, azote, and oxygen, in unknown proportions. As it yields more azotic gas to nitric acid, it has been considered as containing more of that principle than gela-

\* Hatchett, *Phil. Trans.* 1800.† Id. *Ibid.*‡ Id. *Ibid.*

ine. It is obvious, however, that it does not differ much from that body, as nitric acid spontaneously converts it into gelatine. Mr Hatchett has rendered it very probable that it is the first of the soft parts of animals that is formed, and that all the other soft parts are formed from it.

Chap. I.

IV. Like all other animal substances, albumen is capable of existing in various states both when coagulated and uncoagulated, forming a number of distinct species; but they have not been characterized with much precision. But if the curdy part of milk be considered as an albumen, as some chemists do, it constitutes a species essentially distinct from the albumen of eggs and blood. Coagulated albumen forms an essential part of bone and muscle; brain perhaps may be considered as a species of it, and so may the lense of the eye. Cartilage, nails, horns, hair, &c. as Hatchett has shown, are almost entirely composed of it; and it forms the membranous part of many shells, sponges, &c. In short, it is one of the most general and important of the animal substances.

Species of it.

V. The property which albumen has of being coagulated by heat renders it a very useful substance for clarifying liquids. The serum of blood, white of egg, or any liquid containing it, is mixed with the liquid to be clarified, and the whole is then heated. The albumen coagulates, and carries down with it the floating particles which rendered the liquid opaque.

## SECT. III.

## OF MUCUS.

No word in chemistry has been used with less precision than *mucus*. Too many experimenters have it serve as a common name for every animal substance which cannot be referred to any other class. Istock, in his excellent Papers on the Analysis of animal Fluids, has endeavoured to fix the meaning of the word by ascertaining the properties of pure mucus. Fourcroy and Vauquelin have lately written an accurate paper on the same subject \*.

From Bostock's experiments it appears, that if the solid matter obtained by evaporating saliva to dryness is redissolved in water and filtered, the solution will contain very little except mucus. He obtained mucus also, by macerating an oyster in water and evaporating the liquid †. Mucus, thus obtained, possesses the following properties:

1. It has much the appearance of gum arabic excepting that, in general, it is rather more opaque; but it has little taste, dissolves readily in water, and forms an adhesive solution.

---

\* *Ann. du Mus. d'Hist. Nat.* xii. 61.

† *Nicholson's Jour.* xi.



2. When evaporated to dryness it is transparent, inelastic, and has much the appearance of gum. It is insoluble in water, but dissolves readily in all the acids though very much diluted.

3. It does not dissolve in alcohol nor in ether.

4. It does not coagulate when heated; nor when concentrated by evaporation does its solution assume the form of a jelly.

5. It is not precipitated by the oxymuriate of mercury, nor by the infusion of galls\*.

6. The acetate of lead occasions a copious white precipitate when dropt into solutions containing mucus; the superacetate produces a much less striking effect†.

7. Nitrate of silver likewise occasions a precipitate in solutions containing mucus.

8. When heated it assumes the appearance of horn, and when distilled it yields the common products of animal substances. According to Fourcroy and Vauquelin, horn, nails, hair, feathers, the epidermis, and the scales which form on the skin consist chiefly of mucus.

Many of the substances called *mucus* have the property of absorbing oxygen, and of becoming by that means insoluble in water. They resemble vegetable extractive in this respect.

The mucilaginous substances shall be pointed out in the next Chapter. In the present state of our knowledge, any account of them here would merely be a repetition of the properties just mentioned.

\* Bostock, Nicholson's *Jour.* xi. 251.

† Ibid.

‡ Ibid.

1. The first step in the process is to identify the problem or issue that needs to be addressed. This involves gathering information and understanding the context of the problem.

... water in the form of bubbles of  
hydrogen gas which are collected for use  
in a small apparatus in the laboratory, and  
the gas is used for small lamps, and makes  
water of their own. The gas and water are  
separated by the use of a piston at the same  
time as the water. As the water  
is used in the form of gas during  
the process of making, which amounted

er this treatment it might be considered as fibrin  
rly as pure as it can be obtained \*.

Chap. I.

1. Fibrin is of a white colour, has no taste nor smell, Properties.  
is not soluble in water nor in alcohol. When newly  
racted from blood, it is soft and elastic, and resem-  
s very much the gluten of vegetables. Its colour  
pens very much in drying. That which is extracted  
n muscle by boiling and maceration has a certain  
ree of transparency, and is not ductile but brittle.  
colour does not deepen nearly so much as the fibrin  
n blood.

It undergoes no change though kept exposed to the  
on of air; neither does it alter speedily though kept  
ered with water. Mr Hatchett kept a quantity of  
fibrin which he had prepared from beef moistened  
h water during the whole month of April; it ac-  
red a musty but not a putrid smell, neither were the  
es reduced to a pulpy mass. Even when kept two  
nths under water, it neither became putrid, nor was  
verted into the fatty matter obtained by macerating  
nt muscle †.

When fibrin is exposed to heat, it contracts very  
denly, and moves like a bit of horn, exhaling at the  
se time the smell of burning feathers. In a stronger  
t it melts. When exposed to destructive distillation,  
ields water, carbonate of ammonia, a thick heavy  
d oil, traces of acetic acid, carbonic acid, and car-  
eted hydrogen gas ‡. The charcoal, as Hatchett as-  
ained, is more copious than that left by gelatine or  
amen. It is very difficult to incinerate, owing to the  
ence of phosphate of soda and some phosphate of

\* Hatchett, *Phil. Trans.* 1800.

† *Ibid.*

‡ Fourcroy, *ix.* 158.

## Book V.

Action of  
acids.

lime, which form a glassy coat on the surface. A considerable proportion of carbonate of lime also remains after the incineration of the charcoal \*.

3. Acids dissolve fibrin with considerable facility. Sulphuric acid gives it a deep brown colour; charcoal is precipitated, and acetic acid formed. Muriatic acid dissolves it, and forms with it a green coloured jelly. The acetic, citric, oxalic, and tartaric acids, also dissolve it by the assistance of heat; and the solutions, when concentrated, assume the appearance of jelly. Alkalies precipitate the fibrin from acids in flakes, soluble in hot water, and resembling gelatine in its properties †.

Converted  
into gela-  
tine.

Diluted nitric acid occasions the separation of a good deal of azotic gas, as was first observed by Berthollet. Mr Hatchett steeped a quantity of fibrin in nitric acid diluted with thrice its weight of water for 15 days. The acid acquired a yellow tinge, and possessed all the properties of the nitric solution of albumen. The fibrin thus treated, dissolved in boiling water, and when concentrated by evaporation, became a gelatinous mass, soluble in hot water, and precipitated by tan and nitromuriate of tin, and therefore possessing the properties of gelatine. Ammonia dissolves the greater part of the fibrin after it has been altered by nitric acid. The solution is of a deep orange colour, similar to the solution of albumen treated in the same way ‡. Boiling nitric acid dissolves fibrin, except some fatty matter which swims on the surface. The solution resembles that of albumen; except that ammonia throws down a white precipitate, consisting chiefly of oxalate of lime §. Du-

\* Hatchett, Fourcroy, ix. 158.

† Hatchett, *Phil. Trans.* 1800.

‡ Fourcroy, ix. 158.

§ Ibid.



ring the solution, prussic acid comes over, and carbonic acid gas mixed with nitrous gas; a considerable portion of oxalic acid is formed besides the fatty matter which swims\*.

From the recent experiments of Fourcroy and Vauquelin on the muscular fibres of animals, there can be little doubt that fibrin, when treated with hot nitric acid, undergoes a suite of changes. 1. It is first converted into a yellow matter, which still possesses the fibrous texture of fibrin. It has the property of converting vegetable blues to red, has a bitter taste, is but little soluble in water, and is insoluble in alcohol. It combines with alkalies, decomposes their carbonates, unites to oils, and gives them rancidity and acid properties. To this substance Fourcroy and Vauquelin have given the name of *yellow acid*. 2. By the farther action of the nitric acid, this yellow matter becomes more soluble, acquires a reddish tinge, and seems to become soluble in alcohol. 3. The last state into which it is brought by nitric acid seems to be that species of *bitter principle* which crystallizes and detonates when combined with ammonia†.

The alkalies, while diluted, have but little effect upon fibrin; but when concentrated potash or soda is boiled upon it, a complete solution is obtained of a deep brown colour possessing the properties of soap. During the solution ammonia is disengaged. When the solution is saturated with muriatic acid, a precipitate is obtained similar to that from animal soap, except that

Action of  
alkalies.

\* Berthollet and Fourcroy, ix. 153.

† Nicholson's Jour. xiii. 241.

Book V.

it sooner becomes hard and soapy when exposed to the air\*.

The earths, as far as is known, have little or no action on fibrin. Neither has the action of the metallic oxides and salts been examined.

Fibrin is insoluble in alcohol, ether, and oils. The effect of other reagents on it has not been examined.

Composi-  
tion.

4. From the properties above detailed, fibrin appears to be composed of the same constituents as gelatine and albumen; but it probably contains more carbon and azote and less oxygen. The close resemblance which it bears to albumen is very obvious from the experiments of Hatchett just detailed. Nitric acid convert both into *gelatine*, and alkalies convert both into a species of *oil*. Now, as all the soft parts of animals consist of combinations of these three genera, it follows, as Mr Hatchett has observed, that all the soft parts of animals may be either converted into gelatine or animal soap, both substances of the highest importance.

Species.

5. Fibrin exists only in the blood and the muscles of animals: but it is a genus which includes as many species as there are varieties in the muscles of animals; and the great diversity of these substances is well known. The muscles of fish, of fowl, and of quadrupeds, bear scarcely any resemblance to each other.

---

\* Fourcroy, ix, 152, and Hatchett, *Phil. Trans.*, 1800.

## SECT. V.

## OF UREA.

UREA may be obtained by the following process : E. How obtained.  
 vaporate by a gentle heat a quantity of human urine,  
 voided six or eight hours after a meal, till it be reduced to the consistence of a thick syrup. In this state, when put by to cool, it concretes into a crystalline mass. Pour at different times upon this mass four times its weight of alcohol, and apply a gentle heat ; a great part of the mass will be dissolved, and there will remain only a number of saline substances. Pour the alcohol solution into a retort, and distil by the heat of a sand-bath till the liquid, after boiling some time, is reduced to the consistence of a thick syrup. The whole of the alcohol is now separated, and what remains in the retort crystallizes as it cools. These crystals consist of the substance known by the name of *urea* \*.

It was first described by Rouelle Junior in 1773, Discovery.  
 under the name of the *saponaceous extract of urine*. He mentioned several of its properties ; but very little was known concerning its nature till Fourcroy and Vauquelin published their experiments on it in 1799. These celebrated chemists have given it the name of *urea*, which has been generally adopted.

\* Fourcroy and Vauquelin, *Ann. de Chim.* xliii. 26.



Book V.  
Properties.

Urea, obtained in this manner, has the form of crystalline plates crossing each other in different directions. Its colour is yellowish, white: it has a fetid smell, somewhat resembling that of garlic or arsenic; its taste is strong and acrid, resembling that of ammoniacal salts; it is very viscid and difficult to cut, and has a good deal of resemblance to thick honey\*. When exposed to the open air, it very soon attracts moisture, and is converted into a thick brown liquid. It is extremely soluble in water; and during its solution a considerable degree of cold is produced†. Alcohol dissolves it with facility, but scarcely in so large a proportion as water. The alcohol solution yields crystals much more readily on evaporation than the solution in water.

Crystallizes  
with nitric  
acid.

When nitric acid is dropt into a concentrated solution of urea in water, a great number of bright pearl-coloured crystals are deposited, composed of urea and nitric acid. No other acid produces this singular effect. The concentrated solution of urea in water is brown, but it becomes yellow when diluted with a large quantity of water. The infusion of nutgalls gives it a yellowish brown colour, but causes no precipitate; neither does the infusion of tan produce any precipitate‡.

Action of  
heat.

When heat is applied to urea, it very soon melts, swells up, and evaporates with an insupportably fetid odour. When distilled, there comes over first benzoic acid, then carbonate of ammonia in crystals, some carbureted hydrogen gas, with traces of prussic acid and

\* Fourcroy and Vauquelin, *Ann. de Chim.* xixii. 32.—According to Proust, when obtained by the above processes, the urea is saturated with ammonia.—*Jour. de Phys.* lvi. 113.

† Fourcroy and Vauquelin, *Ann. de Chim.* xixii. 32. ; *Ibid.*



there remains behind a large residuum, composed of charcoal, muriate of ammonia, and muriate of soda. The distillation is accompanied with an almost insupportably fetid alliaceous odour. Two hundred and eighty parts of urea yield by distillation 200 parts of carbonate of ammonia, 10 parts of carbureted hydrogen gas, even parts of charcoal, and 68 parts of benzoic acid, muriate of soda, and muriate of ammonia: these last ingredients Fourcroy and Vauquelin consider as foreign substances, separated from the urine by alcohol at the same time with the urea. Hence it follows that 100 parts of urea, when distilled, yield

92.027 carbonate of ammonia  
4.608 carbureted hydrogen gas  
3.225 charcoal

---

99.860

100 parts of carbonate of ammonia, according to Fourcroy and Vauquelin, are composed of 86 ammonia, 12 azotic acid gas, and 24 water. Hence it follows that 100 parts of urea are composed of

39.5 oxygen  
32.5 azote  
14.7 carbon  
13.3 hydrogen

---

100.0

It scarcely be doubted that the water which is contained in the carbonate of ammonia existed ready to combine with the urea before the distillation \*. The solution of urea in water is kept in a boiling

---

\* *Ann. de Chim.* xxxii. 88.

Book V.

ing heat, and new water is added as it evaporates, the urea is gradually decomposed, a very great quantity of carbonate of ammonia is disengaged, and at the same time acetic acid is formed, and some charcoal precipitates\*.

Putrefac-  
tion.

When a solution of urea in water is left to itself for some time, it is gradually decomposed. A froth collects on its surface; air bubbles are emitted which have a strong disagreeable smell, in which ammonia and acetic acid are distinguishable. The liquid contains a quantity of acetic acid. The decomposition is much more rapid if a little gelatine be added to the solution. In that case more ammonia is disengaged, and the proportion of acetic acid is not so great†.

Action of  
sulphuric  
acid,

When the solution of urea is mixed with one-fourth of its weight of diluted sulphuric acid, no effervescence takes place; but, on the application of heat, a quantity of oil appears on the surface, which concretes upon cooling; the liquid which comes over into the receiver contains acetic acid, and a quantity of sulphate of ammonia remains in the retort dissolved in the undistilled mass. By repeated distillations, the whole of the urea is converted into acetic acid and ammonia‡.

Nitric acid,

When nitric acid is poured upon crystallized urea, a violent effervescence takes place, the mixture froths, assumes the form of a dark red liquid, great quantities of nitrous gas, azotic gas, and carbonic acid gas, are disengaged. When the effervescence is over, there remains only a concrete white matter, with some drops of reddish liquid. When heat is applied to this residuum

\* *Ann. de Chim.* xxii. 96.† *Ibid.*‡ *Ibid.* p. 104.

nates like nitrate of ammonia. Into a solution of formed by its attracting moisture from the atmosphere, an equal quantity of nitric acid, of the specific gravity 1.460, diluted with twice its weight of water, was added; a gentle effervescence ensued: a very small quantity of gas was applied, which supported the effervescence for several days. There was disengaged the first day a great quantity of azotic gas and carbonic acid gas; the second day carbonic acid gas, and at last nitrous gas. At the same time with the nitrous gas the smell of the oxy-muriatic acid of Berthollet was perceptible. At the end of the second day, the matter in the retort, which was very thick, took fire, and burnt with a violent explosion. The residuum contained traces of prussic acid and ammonia. The receiver contained a yellowish liquor, on the surface of which some drops of oil

of vitriol dissolved urea, but does not alter it. Oxymuriatic acid gas is absorbed very rapidly by a solution of urea; small whitish flakes appear, which soon become brown, and adhere to the sides of the vessel like a concrete oil. After a considerable quantity of oxymuriatic acid had been absorbed, the solution left to itself, continued to effervesce exceedingly, and to emit carbonic acid and azotic gas. After the effervescence was over, the liquid contained muriate of ammonia.

Muriatic and oxymuriatic acid.

Urea is dissolved very rapidly by a solution of potash, and at the same time a quantity of ammonia is disengaged; the same substance is disengaged when

Action of alkalis.

\* *Ann. de Chim.* xxxii. 107.



Urea is treated with barytes, lime, or even magnesia. Hence it is evident, that this appearance must be ascribed to the carbonate of ammonia, with which it is constantly mixed. When pure solid potash is triturated with urea, heat is produced, a great quantity of ammonia is disengaged; the mixture becomes brown, and a substance is deposited, having the appearance of an empyreumatic oil. One part of urea and two of potash, dissolved in four times its weight of water, when distilled, give out a great quantity of ammoniacal water; the residue contains acetate and carbonate of potash<sup>1</sup>.

When carbonate of soda is dissolved in a solution of urea in water, it is obtained by evaporation, not in cubic crystals, in usual form, but in regular octahedrons. Muriate of ammonia, on the contrary, which crystallizes naturally in octahedrons, is converted into cubes, by dissolving and crystallizing it in the solution of urea.

Such are the properties of this singular substance, as far as they have been ascertained by the experiments of Berzelius and Vauquelin. It differs from all animal substances hitherto examined, in the great proportion of azote which enters into its composition, and in the facility with which it is decomposed, even by the heat of boiling water.

---

<sup>1</sup> Ann. de Chim. xxvii. 307.



## SECT. VI.

## OF SACCHARINE MATTER.

SUGAR has never been found in animals in every respect similar to the sugar of vegetables; but there are animal substances which have so many properties in common with sugar, that they can scarcely be distinguished under any other name. These substances are,

1. Sugar of milk
2. Honey
3. Sugar of diabetic urine.

Sugar of milk may be obtained by the following process: Let fresh whey be evaporated to the consistency of honey, and then allowed to cool; it concretes into a solid mass. Dissolve this mass in water, clarify with the white of eggs, filter and evaporate to the consistence of a syrup; it deposits on cooling a number of brilliant white cubic crystals, which are *sugar of milk*.

How obtained.

Fabricius Bartholdi, an Italian, was the first European who mentioned this sugar. He described it in *Encyclopædia Hermetico Dogmatica*, published at Bologna in 1619; but it seems to have been known in India long before that period. For the best account of its properties we are indebted to Mr Lichtenstein.

When pure it has a white colour, a sweetish taste, no smell. Its crystals are semitransparent regular tetrapipeds, terminated by four-sided pyramids. Its specific gravity, at the temperature of 55°, is 1.543.

Properties.

Book V.

At that temperature it is soluble in seven times its weight of water; but is perfectly insoluble in alcohol: When burnt it emits the odour of caromel, and exhibits precisely the appearance of burning sugar. When distilled, it yields the same products as sugar, only the empyreumatic oil obtained has the odour of benzoic acid\*. When treated with nitric acid it yields *sacclactic* acid. From these experiments, it appears that sugar of milk is specifically different from every kind of vegetable sugar at present known†.

Honey.

2. Honey is prepared by bees, and perhaps rather belongs to the vegetable than the animal kingdom. It has a white or yellowish colour, a soft and grained consistence, a saccharine and aromatic smell. By distillation it affords an acid phlegm and an oil, and its cal is light and spongy like that of the mutilages of plants. Nitric acid extracts from it oxalic acid, precisely as it does from sugar. It is very soluble in water, with which it forms a syrup, and like sugar passes to the vinous fermentation. Mr Cavezzali has lately affirmed that honey is composed of sugar, mucilage, and an acid. The sugar may be separated by melting the honey, adding carbonate of lime in powder as long as any effervescence appears, and scumming the solution while hot. The liquid thus treated gradually deposits cry-

---

\* Scheele, ii. 70.

† If the reader wishes a more detailed account of sugar of milk, he may consult Lichtenstein's *Abhandlung*, published separately in 1772, and Rouelle's dissertation in the 39th volume of the *Jour. de Médecine*. An abridged view of the whole has been given by Morveau in the 1st volume of the *Encycl. Méthodique*, which has been published in an English dress by Mr Johnson in his *History of Animal Chemistry*, i. 128.

stals of sugar when allowed to remain in a glass vessel<sup>a</sup>.

Chap. I.

According to Proust, there are two kinds of honey; one always liquid, and the other solid and not deliquescent. They may be separated, he says, by means of alcohol<sup>†</sup>.

3. The urine of persons labouring under the disease known to physicians by the name of *diabetes*, yields, when evaporated, a considerable quantity of matter which possesses properties analogous to sugar. This seems to have been first observed by Willis. Afterwards the subject was carried somewhat farther by subsequent physicians. But it is to Mr Cruikshanks that we are indebted for the most valuable set of experiments on the subject. In this case he extracted from urine about  $\frac{1}{11}$ th of its weight of a sweet-tasted extract like honey. When treated with nitric acid, it yielded the same proportion of oxalic acid as an equal quantity of common sugar would have done, making allowance for the saline substances present. No saccharic acid was formed. Hence it follows that this substance is not analogous to sugar of milk, but nearer common sugar in its properties. It has been supposed incapable of crystallizing regularly like common sugar. But I have seen it prepared by Dr Wollaston in small grains having almost exactly the appearance of common white sugar. Nicolas affirms that when treated with lime it is decomposed<sup>‡</sup>. If so, it certainly differs essentially from common sugar, which Cruikshanks first proved to be capable of uniting to lime without decomposition.

Sugar of  
diabetic  
urine.

<sup>a</sup> *Ann. de Chim.* xxxix. 110.

<sup>†</sup> *Jour. de Phys.* lxx. 428.

<sup>‡</sup> *Ann. de Chim.* xlv. 64.

Book V.

4. Thenard has lately detected a peculiar matter in bile, which he considers as saccharine. I shall give an account of its properties when treating of that animal fluid.

---

## SECT. VII.

### OF OILS.

THE oily substances found in animals belong all to the class of fixed oils. They differ very much in their consistence, being found in every intermediate state from spermaceti, which is perfectly solid, to train oil, which is completely liquid. The most important of them are the following :

- Spermaceti.** 1. *Spermaceti*.—This peculiar oily substance is found in the cranium of the *physeter macrocephalus*, or spermaceti whale. It is obtained also from some other species. At first it is mixed with some liquid oil, which is separated by means of a woollen bag. The last portions are removed by an alkaline ley, and the spermaceti is afterwards purified by fusion. Thus obtained it is a beautiful white substance, usually in small scales, very brittle, has scarcely any taste, and but little smell. It is distinguished from all other fatty bodies by the crystalline appearance which it always assumes. It melts, according to the experiments of Bostock, at the temperature of  $112^{\circ}$ °. When sufficiently heated it may

**Properties.**

---

\* Nicholson's Jour. iv. 134.



be distilled over without much alteration; but when distilled repeatedly it loses its solid form and becomes a liquid oil \*. From the experiments of Thouvenel and Crell, we learn that by repeated distillation it is partly decomposed, and a brown acid liquid obtained. It is soluble in boiling alcohol, but separates again as the solution cools. About 150 parts of alcohol are necessary to dissolve it†. Ether dissolves it cold, and very rapidly when hot; on cooling the whole concretes into a solid mass‡. It dissolves also in hot oil of turpentine, but precipitates again as the liquid cools§.

The acids have scarcely any action on it; but it unites readily with the pure alkalies, as was shown long ago by Crell, and the fact has been lately confirmed by Dr Bostock. With hot ammonia it forms an emulsion which is not decomposed by cooling nor by water; but the spermaceti is immediately thrown down by the addition of an acid||. It dissolves sulphur, and is dissolved by the fixed oils. When long exposed to the air it becomes yellow and rancid. This substance is employed like wax and tallow for making candles. It is said also, that if bits of caoutchouc be thrown into it while melted, they are dissolved, and form a compound which answers remarkably well for luting vessels¶.

2. *Fat*.—This substance is found abundantly in different parts of animals. When pure it possesses the properties of the fixed oils. Its consistence varies from

\* Neumann.

† Fourcroy and Bostock, Nicholson's *Jour.* iv. 134.

‡ Bostock, *Ibid.*

§ *Ibid.*

|| *Ibid.*

¶ Nicholson's 4to *Jour.* i. 472.

## ANIMAL SUBSTANCES.

*7.* ~~adipose~~ *ordure*, which is brittle, to *hog's lard*, which is soft and semifluid. To obtain fat pure, it is in small pieces, well washed in water, and the meninges, parts and vessels separated. It is then melted in a shallow vessel along with some water, and kept until the water is completely evaporated. Thus refined it is white, tasteless, and nearly insipid. *Properties.* Different kinds of it liquefy at different temperatures. Lard melts at  $97^{\circ}$ ; but the fat extracted from it by boiling requires, according to Nicholson, a heat of  $170^{\circ}$ . When heated to about  $400^{\circ}$ , it begins to emit a smoke, which becomes more copious and more greasy as the heat increases; at the same time, it comes blackish, owing doubtless to the decomposition of a portion of it and the evolution of some charcoal. If it be now cooled it becomes more brittle and solid at first. When hog's lard is distilled in a retort, we obtain first a portion of water, and then a white oil which concretes in the receiver into small globules; and a black mass remains in the retort. In the whole process abundance of carburated hydrogen and carbonic acid come over, which have a most minable odour. When the vessels are unluted, they emit an odour so detestable and powerful that it is absolutely impossible to endure it. It was formerly supposed that this odour was exhaled by the sebaceous matter formed during the process; but Thenard has shown this to be a mistake. We must therefore ascribe it to an empyreumatic oil. The smell does not suddenly disappear. During this distillation acetic acid is engaged, and likewise some sebamic acid, which is in solution in the receiver mixed with the oil. These products demonstrate the peculiar nature of

Book V.  
Train oil.

3. *Train oil*.—This liquid is extracted from the blubber of the whale, and from other fish. It forms a very important article of commerce, being employed for combustion in lamps, and for other purposes. It is at first thick; but on standing, a white mucilaginous matter is deposited, and the oil becomes transparent. It is then of a reddish brown colour, and has a disagreeable smell. If it be agitated with a little sulphuric acid, and then mixed with water, the oil, when allowed to settle, swims on the surface, of a much lighter colour than before, the water continues milky, and a curdy matter is observed swimming between the oil and water. This method has been employed for purifying the oil, to make it more proper for burning in lamps. Various other methods have been employed. The most important are those recommended by Mr Dossie\*.

Spermaceti  
oil.

4. *Spermaceti oil*.—This is the oil which separates from spermaceti during the purification of it. It is much purer than train oil, and therefore answers better for burning in lamps.

Butter.

5. *Butter* possesses all the characters of a fixed oil, but as it is not found ready formed in any animal substance, the detail of its properties belongs to the next Chapter.

Oil of ants.

6. *Oil of ants*.—Margraff obtained this oil by macerating the *formica rufa* in water, and distilling off one-half of the liquid. The oil was found swimming upon the surface of the water in the receiver. It is liquid, and dissolves completely in alcohol. Its taste is

---

\* See *Phil. Mag.* xv. 105; and the *Transactions of the Society for the Encouragement of the Arts*, vol. xx.

not hot, but it has a peculiar smell. It appears to be intermediate between fixed and volatile oils in its properties\*.

7. Though all the oily bodies found in animal substances belong to the class of fixed oils, yet there is a peculiar volatile oil which makes its appearance, and which is doubtless formed during the distillation of different animal bodies. Though this oil has now lost that celebrity which drew the attention of the older chemists to it, yet as its properties are peculiar, a short account of it will not be improper. It is usually called the *animal oil of Dippel*, because that chemist first drew the attention of chemists to it. It is usually obtained from the gelatinous and albuminous parts of animals. The horns are said to answer best. The product of the first distillation is to be mixed with water, and distilled with a moderate heat: the oil which is first obtained is the animal oil of Dippel.

Animal oil  
of Dippel.

It is colourless and transparent; its smell is strong and rather aromatic; it is almost as light and as volatile as ether; water dissolves a portion of it; and it changes syrup of violets green, owing, as is supposed, to its containing a little ammonia. The acids all dissolve it, and form with it a kind of imperfect soap. Nitrous acid sets it on fire. It forms with alkalies a soap. Alcohol, ether, and oils unite with it. When exposed to the air it becomes brown, and loses its transparency. It was formerly used as a specific in fevers†.

\* Margraff, *Opusc.* i. 291.

† See the experiments of Meinel and Dehne.



## SECT. VIII.

## OF ANIMAL RESINS.

SUBSTANCES resembling resins are found in different animal bodies ; and which, for that reason, may be called *animal resins*. Their properties are somewhat different from the vegetable resins, but they have not been all examined with precision. The following are the most remarkable of these substances.

Resin of  
bile.

1. *Resin of bile*.—This substance may be obtained by the following process : Into 32 parts of fresh ox bile pour one part of concentrated muriatic acid. After the mixture has stood for some hours, pass it through a filter, in order to separate a white coagulated substance. Pour the filtrated liquor, which has a fine green colour, into a glass vessel, and evaporate it by a moderate heat. When it has arrived at a certain degree of concentration, a green-coloured substance precipitates. Decant off the clear liquid, and wash the precipitate in a small quantity of pure water. This precipitate is the *basin of bile*, or the *resin of bile*, as it is sometimes called \*.

Properties.

The resin of bile is of a dark brown colour ; but when spread out upon paper or on wood, it is a fine grass green : its taste is intensely bitter †.

When heated to about 122° it melts ; and if the heat

\* Cadet, *Mém. Par.* 1767, p. 340.

† Ibid. p. 341.

be still farther increased it takes fire and burns with rapidity. It is soluble in water, both cold and hot, and still more soluble in alcohol; but water precipitates it from that liquid\*.

It is soluble also in alkalies, and forms with them a compound which has been compared to a soap. Acids, when sufficiently diluted, precipitate it both from water and alkalies without any change; but if they be concentrated, the precipitate is redissolved†.

From these properties, it is clear that the resin of bile has a considerable resemblance to vegetable resins; but it differs from them entirely in several of its properties. The addition of oxygen, with which it combines readily, alters it somewhat, and brings it nearer to the class of oils.

In this altered state the resin of bile may be obtained by the following process: Pour oxymuriatic acid cautiously into bile till that liquid loses its green colour; then pass it through a filter to separate some albumen which coagulates. Pour more oxymuriatic acid into the filtered liquid, and allow the mixture to repose for some time. The oxymuriatic acid is gradually converted into common muriatic acid; and in the mean time the basis of bile absorbs oxygen, and acquires new properties. Pour into the liquid, after it has remained a sufficient time, a little common muriatic acid; a white precipitate immediately appears, which may be separated from the fluid. This precipitate is the basis of bile combined with oxygen.

It has the colour and the consistence of tallow, but

\* Fourcroy, *Ann. de Chim.* vii. 178.

† Cadet and Macbarg.

Book V.

still retains its bitter taste. It melts at the temperature of  $104^{\circ}$ . It dissolves readily in alcohol, and even in water, provided it be assisted by heat. Acids precipitate it from these solutions\*.

The resinous substance discovered by Proust in humane urine does not seem to differ much from the resin of bile. Ear-wax also, from the experiments of Vauquelin, contains a resin which possesses the same properties.

Ambergris.

2. *Ambergris*.—This substance is found floating on the sea, near the coasts of India, Africa, and Brazil, usually in small pieces, but sometimes in masses of 50 or 100 pounds weight. Various opinions have been entertained concerning its origin. Some affirmed that it was the concrete juice of a tree†; others thought it a bitumen; but it is now considered as pretty well established, that it is a concretion formed in the stomach or intestines of the *physter macrocephalus*, or spermæcti whale‡.

Properties.

Ambergris when pure is a light soft substance which swims on water. Its specific gravity varies from 0.78 to 0.92, according to Brisson; Bouillon La Grange, who has lately published an analysis of it, found its specific gravity from 0.849 to 0.844§. Its colour is ash grey, with brownish yellow and white streaks. It has an agreeable smell, which improves by keeping. Its taste is insipid.

When heated to  $122^{\circ}$  it melts without frothing; if

---

\* Fourcroy, *Ann. de Chim.* vii. 176.

† See the New Abridgement of the *Phil. Trans.* ii. 29.

‡ See *Phil. Trans.* vols. xxxii. xxxviii. and xc.

§ *Ann. de Chim.* xlvii. 73.



heat be increased to  $212^{\circ}$ , it is volatilized completely in a white smoke, leaving only a trace of charcoal.

When distilled, we obtain a whitish acid liquid and a light volatile oil; a bulky charcoal remains behind.

It is insoluble in water. Acids have little action on it.

Weak sulphuric acid occasions no change; but when concentrated it develops a little charcoal. Nitric acid dissolves it, giving out at the same time nitrous gas, carbonic acid, and azotic gas. A brownish liquid is formed, which leaves, when evaporated to dryness, a little brown substance, possessing the properties of resin. The alkalis dissolve it by the assistance of heat, and form a soap soluble in water. Both the fixed and volatile oils dissolve ambergris. It is soluble also in ether and alcohol †.

When 100 parts of ambergris are macerated for twenty-four hours in 16 parts of alcohol, the liquid assumes a deep yellow colour. By repeating the process, the alcohol takes up the whole that is soluble. Hot alcohol dissolves the rest, except a little resinous matter easily separated by filtration. It weighs 1.2 parts. The cold infusions of alcohol being evaporated to dryness, there remains a brown brilliant substance, which is readily melted by heat, and which volatilizes completely when put upon hot charcoal. This substance possesses the properties of a resin. It amounts to 30.8 parts. It is precipitated from alcohol by water, leaving a portion of benzoic acid, which may likewise be separated from ambergris by heat, and by

Analysis.

Bouillon La Grange, *Ann. de Chim.* xlvii. 73.

† *Ibid.* 75.

Vol. V.

H h



Book V.

the usual process by which it is extracted from benzoïn. It amounts to 11.1 parts. When the hot alcohol infusion is allowed to cool, it lets fall the portion of ambergris which it held in solution. This substance is of a pale yellow colour, and easily softens by heat. When slowly cooled, it assumes a lamellar form. It possesses the properties of the fatty matter into which the muscles are converted by nitric acid, and which makes its appearance when dead bodies are allowed to putrefy in great numbers together. This substance has been distinguished by the name of *adipocire*, from its resemblance both to fat and wax. The quantity of it in ambergris amounts to 52.8 parts. Such is the analysis of ambergris made by Bouillon La Grange. This substance, then, according to that chemist, is composed of.....

Constitu-  
ents.

52.7 adipocire

30.8 resin

11.1 benzoic acid

5.4 charcoal

---

 100.0 \*

Propolis.

3. *Propolis*. This is a substance collected by bees newly placed in a hive. They employ it to cover the bottom of the hive, and to coat over all foreign substances which are too heavy to be removed. The bees bring it on their legs and feet; to which it adheres so strongly that the insect cannot extricate itself; but its associates pull it off with their jaws, and apply it to immediate use. It is probably a vegetable production; but as this is not known for certain, and as it is prepared by animals, I have reserved an account of its pro-

\* *Ann. de Chim.* xi.

properties for this place. Vauquelin has lately subjected it to a chemical analysis.

Chap. I.

Properties.

It is at first soft and ductile, but it gradually hardens and becomes solid. In large masses it appears blackish; but in thin pieces it is semitransparent. The heat of the fingers is sufficient to soften it, and give it the ductility of wax; but it is more ropy and tenacious. It is tasteless, but has an aromatic odour similar to that of balsam of Peru. When macerated in alcohol, it tinges the liquid of a deep red colour; and by repeating the maceration, the portion soluble is separated. Boiling alcohol dissolved another portion of it; and by repeated decoctions 100 parts of propolis were reduced to 14, which consisted of extraneous bodies. All the alcoholic solutions were mixed and passed through a fine strainer, which separated the portion that precipitated as the decoction cooled. This substance, when properly dried, possessed the properties of wax. The alcohol was now concentrated by distillation, then mixed with water, and boiled. A resinous mass was obtained of a reddish brown colour, semitransparent, and very brittle. It weighed 57 parts. The water in which it had been boiled contained an acid, probably the benzoic. By distillation the resinous matter yielded a volatile oil, and became harder. This resin is soluble in fixed and volatile oils, and very similar in its properties to the resin of balsam of Peru. Thus 100 parts of propolis

Book V.  
Constitu-  
ents.

57 resin

14 wax

14 impurities

15 acid and loss

---

 100 \*

Castor.

4. *Castor*. This substance is obtained from the beaver. In each of the inguinal regions of that animal there are two bags, a large and a small. The large one contains the true castor; the small one a substance which has some resemblance to it, but which is in much less estimation. We are indebted to Bouillon La Grange for a set of experiments on it †.

Properties.

Castor is of a yellow colour; and when newly taken from the animal it is nearly fluid. But by exposure to the atmosphere it gradually hardens, becomes darker coloured, and assumes a resinous appearance. Its taste is bitter and acrid, and its odour strong and aromatic. In water it softens, and tinges the liquid of a pale yellow colour. The infusion gives a green colour to vegetable blues, and contains an alkali. By long continued maturation a deeper coloured infusion is obtained, which yields a dry extract of a tortoise shell colour, soluble in ether and alcohol. Water precipitates a resinous substance from the alcohol. From the analysis of Bouillon La Grange, we learn that castor contains the following ingredients:

Constitu-  
ents.

1. Carbonate of potash
2. Carbonate of lime
3. Carbonate of ammonia

---

\* Nicholson's Jour. v. 48.

† Jour. de Phys. xlii. 65.



4. Iron
5. Resin
6. A mucilaginous extractive matter
7. A volatile oil

The properties of the resin are analogous to those of the resin of bile.

5. *Civet*.—This substance, like the last, is obtained from the inguinal region of the *civet cat*. It is squeezed out of the cavity where it is secreted every other day. It is employed as a perfume, but has not hitherto engaged the attention of chemists. Its colour is yellow; its consistence that of butter; its smell so strong as to be agreeable only when much reduced by mixture with other bodies. It unites readily with oils, but is said not to dissolve in alcohol. In that case it ought to be excluded from the class of resinous bodies.

6. *Musk*.—This substance is secreted into a kind of bag situated in the umbilical region of the quadruped called *moschus moschifer*. Its colour is brownish red; it feels unctuous; its taste bitter; and its smell aromatic and intensely strong. It is partially soluble in water, which acquires its smell; and in alcohol, but that liquid does not retain the odour of musk. Nitric and sulphuric acids dissolve it, but destroy the odour. Fixed alkalies develop the odour of ammonia. Oils do not act on it. At a red heat it has the same fetid smell as urine\*. Its component parts have not been ascertained.

7. The *formica rufa*, or red ant, contains also a peculiar resin, as has been proved by Fourcroy and Vauquelin†.

\* Neumann.

† *Phil. Mag.* xv. 148.



## SECT. IX.

## OF SULPHUR AND PHOSPHORUS.

THESE two simple combustibles constitute a part of many animal substances; but in what state of combination they exist in them has not been ascertained. All that can be done therefore at present is to mention some of the bodies from which they may be separated.

Sulphur.

1. Sulphur seems to be a never-failing attendant on albumen, in whatever part of the body that substance exists as a constituent. Scheele ascertained its presence in the white of an egg and in milk \*; Parmentier and Deyeux in the blood †; Proust in urine and fæces, in the muscles, in hair, &c. and he has made it probable that sulphur is mixed with the matter which is transpired from the body ‡. This chemist informs us, that in the blood it is combined with ammonia in the state of hydrosulphuret of ammonia; but whether it be in the same state in other parts of the body is not known.

Phosphorus.

2. Phosphorus exhales from different animal bodies during putrefaction in the state of phosphureted hydrogen gas, and of course must have been a constituent part of these bodies. The luminous appearance which

\* Scheele, ii. 57.

† *Jour. de Phys.* lliv. 437.‡ *Ann. de Chim.* XLVI. 258.

ne animals exhibit seems, in several instances, to be  
ing to the presence of this very combustible sub-  
stance: But the experiments hitherto made upon these  
mals are not sufficiently decisive.

Chap. I.

## SECT. X.

### OF ACIDS.

THE acids which have been discovered ready formed, Acids.  
constituting a part of animal bodies, are the fol-  
lowing:

- |               |             |
|---------------|-------------|
| 1. Phosphoric | 7. Rosacic  |
| 2. Sulphuric  | 8. Amniotic |
| 3. Muriatic   | 9. Oxalic   |
| 4. Carbonic   | 10. Formic  |
| 5. Benzoic    | 11. Acetic  |
| 6. Uric       | 12. Malic.  |

1. The phosphoric acid is by far the most abundant Phosphoric.  
all the acids found in animals. Combined with lime,  
constitutes the basis of bone; and the phosphate of  
e is found in the muscles, and almost all the solid  
ts of animals; neither are there many of the fluids  
n which it is absent. In the blood, phosphoric acid  
found combined with oxide of iron; and in the urine  
exists in excess, holding phosphate of lime in solution.

2. Sulphuric acid can scarcely be considered as a Sulphuric.  
ponent part of any of the substances belonging to  
human body. It is said, indeed, to occur some-

Book V. times in urine combined with soda. It is, however, a very common constituent of the liquid contents of the inferior animals. Thus sulphate of soda is found in the liquor of the amnios of cows, and sulphate of lime occurs usually in the urine of quadrupeds.

Muriatic. 3. Muriatic acid occurs in most of the fluid animal substances, and is almost always combined with soda, constituting common salt.

Carbonic. 4. Carbonic acid has been detected in fresh human urine by Proust, and it occurs in the urine of horses and cows abundantly, partly combined with lime.

Benzoic. 5. Benzoic acid was first discovered in human urine by Scheele; and Fourcroy and Vanquelin have found it abundantly in the urine of cows. Proust has detected it in the blood, the albumen of an egg, in glut, silk, and wool, in the sponge, different species of algae, and even in mushrooms. This chemist even thinks it probable that it is a constituent of all substances which contain azote\*. Or more probably it is formed during the action of reagents on these substances.

Uric. 6. Uric or lithic acid was discovered by Scheele in 1776. It is the most common constituent of urinary calculi, and exists also in human urine. That species of calculus which resembles wood in its colour and appearance is composed entirely of this substance. It was called at first lithic acid; but this name, in consequence of the remarks made by Dr Pearson on its impropriety, has been laid aside, and that of uric acid substituted in its place†.

\* *Ann. de Chim.* xxxvi. 271.

† Dr Pearson rather chose to call it oxalic.



7. *Rosacic*. During intermittent fevers urine deposits a very copious precipitate, which has been long known to physicians under the name of *lateritious sediment*. This sediment always makes its appearance at the crisis of fevers. In gouty people, the same sediment appears in equal abundance towards the end of a paroxysm of the disease; and if this sediment suddenly disappears after it has begun to be deposited, a fresh attack may be expected\*. Scheele considered this sediment as uric acid mixed with some phosphate of lime; and the same opinion has been entertained by other chemists: but Proust affirms that it consists chiefly of a different substance, to which he has given the name of *rosacic acid* from its colour, mixed with a certain proportion of uric acid and phosphate of lime. This *rosacic acid*, he informs us, is distinguished from the uric by the facility with which it dissolves in hot water, the violet precipitate which it occasions in muriate of gold, and by the little tendency which it has to crystallize†.

Chap. I.  
Rosacic.

8. *Amniotic acid* has been lately discovered by Vauquelin and Buniva in the liquor of the amnios of the cow, and may be obtained in white crystals by evaporating that liquid slowly. Hence they have given it the name of *amniotic acid*. It is of a white and brilliant colour; its taste has a very slight degree of sourness; it reddens the tincture of turnsole; it is scarcely soluble in cold water, but very readily in hot water, from which it separates in long needles as the solution cools. It is soluble also in alcohol, especially when assisted by heat.

Amniotic.

\* Crutwickshanks, *Phil. Mag.* ii. 249.    † *Ann. de Chim.* lxxvi. 265.



## Book V.

It combines readily with pure alkalies, and forms a substance which is very soluble in water. The other acids decompose this compound; and the acid of the liquor of the amnios is precipitated in a white crystalline powder. This acid does not decompose the alkaline carbonates at the temperature of the atmosphere, but it does so when assisted by heat. It does not alter solutions of silver, lead, or mercury, in nitric acid. When exposed to a strong heat it froths, and exhales an odour of ammonia and of prussic acid. These properties are sufficient to show that it is different from every other acid. It approaches nearest to the saccharic and the uric acids; but the first of these does not furnish ammonia by distillation like the amniotic; The uric acid is not so soluble in hot water as the amniotic; it does not crystallize in white brilliant needles, and it is insoluble in boiling alcohol: in both which respects it differs completely from amniotic acid\*.

## Oxalic.

9. Oxalic acid has hitherto been found only in a few urinary calculi by Vauquelin and Fourcroy.

10. Formic acid has been hitherto found only in the *formica rufa*, or red ant. The details have been already given in a preceding part of this Work.

## Acetic.

11. Acetic. This acid has been detected in urine by Proust. It exists also in the *formica rufa*, or red ant, as has been demonstrated by the experiments of Fourcroy and Vauquelin. It appears also, from the labours of these philosophers and of Thenard, that the acid found in milk is the acetic, disguised a little by holding some salts in solution.

---

\* *Ann. de Chim.* xxiii. 279.

12. Malic acid. This acid has been lately detected by Fourcroy and Vauquelin in the acid liquid obtained from the *formica rufa*. When this liquid is saturated with lime, if acetate of lead be dropt into the solution, a copious precipitate falls, which is soluble in acetic acid. Fourcroy and Vauquelin exposed the precipitate to the proper trials, and ascertained that it was malate of lead.

Chap. I.  
Malic.

Besides the acids enumerated above, several others have been mentioned by chemical writers. The truth is, that a variety of acid liquors have been observed in animals; but as these have not been examined, we do not know whether they are peculiar substances, or merely some of those already enumerated. Chaussier, in 1781, pointed out an acid in the silk worm, which has been called *bombic acid*\*. But the list of its properties which he has given is altogether insufficient to constitute it a peculiar substance; and all subsequent accounts of it which I have seen are mere repetitions of the original paper. Dehne obtained an acid from the insects called *meloe proscarabæus* and *majalis*. Chaussier obtained an acid from the grasshopper and the bug. In short, acids are obtained from many of the insect tribe; and from the experiments published, it is extremely probable that in most of these insects the acid is the acetic.

Other acids.

---

\* *Mém. Dijon*, 1783, ii. 70.

---

---

SECT. XI.

## OF ALKALIES, EARTHS, AND METALS.

I. **ALL** the alkalies have been found in the fluids of animals.

**Potash.** 1. Potash is rather uncommon in the human fluids; but it has been detected in the milk of cows, and it has been found abundantly in the urine of quadrupeds.

**Soda.** 2. Soda exists in all the fluids, and seems always to be combined with albumen. Phosphate and muriate of soda are also found. It is this alkali which gives animal fluids the property of tinging vegetable blues green.

**Ammonia.** 3. Ammonia has been detected by Proust in urine; and it is formed in abundance during the putrefaction of most animal bodies.

II. The only earths hitherto found in animals are lime, magnesia, and silica.

**Lime.** 1. Lime exists in great abundance in all the larger animals. Combined with phosphoric acid, it constitutes the basis of bones, while shells are composed of carbonate of lime. Phosphate of lime is found also in the muscles and other solid parts, and it is held in solution by almost all the fluids.

**Magnesia.** 2. Magnesia has been detected in human urine by Fourcroy and Vauquelin, combined with phosphoric

acid and ammonia. It constitutes also sometimes a component part of the urinary calculi.

Chap. I.

3. Silica has not hitherto been detected in any of the component parts of animals, except hair; but Fourcroy and Vauquelin found it in urinary calculi.

Silica.

III. The metals found in animals are two; namely, iron and manganese.

1. Iron combined with phosphoric acid is a constituent part of the blood. Its presence was first ascertained by Manghini, who proved at the same time that it does not exist in the solid parts of animals. It is said to exist also in bile.

Iron.

2. Manganese has been found in human hair, but scarcely in any other animal substance.

Manganese.

## SECT. XII.

### OF ANIMAL PRINCIPLES IN GENERAL.

SUCH are the properties of all the animal substances hitherto detected and accurately examined. They are by no means so numerous as the vegetable principles, owing in all probability to the chemical examination of animals having been hitherto confined to a small number, while a much more extensive range has been taken in the vegetable kingdom. The inferior animals, if we except a few insects, have attracted but little of the attention of chemists. I confess, too, that I have omitted on purpose an account of several principles which are well known to exist in the animal kingdom, merely

Substances omitted.



Book V.

because we know nothing so precise about their chemical properties as to enable us to class them properly. I may mention, as examples, the colouring matter of the cochineal insect, and that of the shell-fish with which the ancients dyed their purple. The reader will find a very full and interesting account of all that we know respecting these substances in Dr Bancroft's *Philosophy of Permanent Colours*. I may mention also the liquor emitted by the ink-fish, and the blistering principle in *cantharides*. Experiments, indeed, have been made on the last by Neumann, and others since his time; but they are still very incomplete, since we do not even know what the blistering principle is, tho' it is likely enough that it is a resin.

Almost the whole of the soft parts of animal bodies consist of gelatine, albumen, fibrin, and oil; while the basis of the hard parts is either phosphate or carbonate of lime. The other animal principles occur only in small quantities, and particular parts of the animal. The oils seldom enter into the structure of the organs of animals: they serve rather to lubricate the different parts, and to fill up interstices. Gelatine is insoluble in cold water, albumen insoluble in hot, and fibrin insoluble both in cold and hot.

Simple substances  
found in  
animals.

The simple bodies of which all of them consist are the following:

- |               |                   |
|---------------|-------------------|
| 1. Azote      | 8. Soda           |
| 2. Carbon     | 9. Potash         |
| 3. Hydrogen   | 10. Muriatic acid |
| 4. Oxygen     | 11. Magnesia      |
| 5. Phosphorus | 12. Silica        |
| 6. Lime       | 13. Iron          |
| 7. Sulphur    | 14. Manganese     |

Of these, magnesia and silica may in a great measure be considered as foreign bodies; for they are only found in exceedingly minute quantities. The principle elementary ingredients are the first six: animal substances may be considered as in a great measure composed of them. The first four constitute almost entirely the soft parts, and the other two form the basis of the hard parts. But we will be able to judge of this much better after we have taken a view of the various parts of animals as they exist ready formed in the body. This shall be the subject of the next Chapter.

## CHAP. II.

## PARTS OF ANIMALS.

## Solids.

THE different substances which compose the bodies of animals may be arranged under the following heads:

- |                          |                              |
|--------------------------|------------------------------|
| 1. Bones and shells      | 7. Glands                    |
| 2. Horns and nails       | 8. Brain and nerves          |
| 3. Muscles               | 9. Marrow                    |
| 4. Skin                  | 10. Hair and feathers        |
| 5. Membranes             | 11. Silk and similar bodies. |
| 6. Tendons and ligaments |                              |

Besides these substances, which constitute the solid parts of the bodies of animals, there are a number of fluids, the most important of which is the *blood*, which pervades every part of the system in all the larger animals: The rest are known by the name of *secretions*, because they are formed, or *secreted* as the anatomists term it, from the blood. The principal animal secretions are the following:

## Fluids.

- |                              |                            |
|------------------------------|----------------------------|
| 1. Milk                      | 9. Humours of the eye      |
| 2. Eggs                      | 10. Mucus of the nose, &c. |
| 3. Saliva                    | 11. Sinovia                |
| 4. Pancreatic juice          | 12. Semen                  |
| 5. Bile                      | 13. Liquor of the amnios   |
| 6. Cerumen                   | 14. Poisonous secretions   |
| 7. Tears                     | 15. Air.                   |
| 8. Liquor of the pericardium |                            |

Various substances are separated either from the blood or the food, on purpose to be afterwards thrown out of the body as useless or hurtful. These are called *secretions*. The most important of them are,

1. Sweat
2. Urine
3. Fæces.

Besides the liquids which are secreted for the different purposes of healthy animals, there are others which make their appearance only during disease, and which may therefore be called *morbid secretions*. The most important of these are the following :

1. Pus
2. The liquor of dropsy
3. The liquor of blisters.

Morbid secretions.

To these we must add several solid bodies, which are occasionally formed in different cavities in consequence of the diseased action of the parts. They may be called *morbid concretions*. The most remarkable of them are the following :

1. Salivary calculi
2. Concretions in the lungs, liver, brain, &c.
3. Intestinal calculi
4. Biliary calculi
5. Urinary calculi
6. Gouty calculi.

Morbid concretions.

These different substances shall form the subjects of the following sections :



## SECT. I.

## OF BONES, SHELLS, AND CRUSTS.

Bones,  
what.

By *bones* are meant those hard, solid, well-known substances, to which the firmness, shape, and strength of animal bodies are owing; which, in the larger animals, form as it were the ground work upon which all the rest is built. In man, in quadrupeds, and many other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but shell-fish and snails have a hard covering on the outside of their bodies, evidently intended for defence. As these coverings, though known by the name of *shells*, are undoubtedly of a bony matter, I shall include them in this Section. For the very same reason, it would be improper to exclude *egg-shells*, and those coverings of certain animals, the lobster for instance, known by the name of *crusts*. The solid substances belonging to that class of bodies usually distinguished by the name of *zoophytes*, may be included likewise without impropriety in this Section. As these different substances, though they belong to the same genus, are notwithstanding distinguished by peculiar properties, I shall consider each set separately.

## I. BONES.

Properties.

THE bones are the most solid part of animals. Their texture is sometimes dense, at other times cellular and

porous, according to the situation of the bone. They are white, of a lamellar structure, and not flexible nor softened by heat. Their specific gravity differs in different parts. That of adults teeth is 2.2727; the specific gravity of childrens teeth is 2.0833\*. It must have been always known that bones are combustible, and that when sufficiently burnt, they leave behind them a white porous substance, which is tasteless, absorbs water, and has the form of the original bone. The nature of this substance embarrassed the earlier chemists. Beccher observed, that in a very violent heat it underwent a kind of fusion, and assumed an appearance analogous to that of porcelain. It was afterwards considered as a peculiar earth, and distinguished by the name of *animal earth* or *earth of bones*. Some chemists considered it as the same with lime; but the difference between it and that earth was too well marked to allow that opinion to gain ground. It had been long known that bones yielded a gelatinous substance when boiled in water; they had even been employed in the manufacture of glue. Hence it was obvious that they contained gelatine. It had been observed, that all acids had the property of softening them by dissolving their earthy and gelatinous constituents; and that when thus softened they resembled cartilage. These facts must have been known at a very early period, and afforded chemists some data for estimating their constituents.

History.

In 1771, Scheele mentioned, in his dissertation on fluor spar, that the earthy part of bones is *phosphate of*

---

\* Pcpys, *For on the Teeth*, p. 99.

Book V.

*lime* \*. This discovery was the first and the great step towards a chemical knowledge of the composition of bones. Afterwards some new facts were made known by Berniard, Bouillon, and Rouelle: but for by far the most complete analyses which have hitherto appeared we are indebted to Mr Hatchett †, and to Fourcroy and Vauquelin ‡.

Constitu-  
ents.

The component parts of bones are chiefly four; namely, the earthy salts, fat, gelatine, and cartilage.

1. Earthy  
salts.

1. The earthy salts may be obtained either by calcining the bone to whiteness, or by steeping it for a sufficient length of time in acids. In the first case, the salts remain in the state of a brittle white substance; in the second, they are dissolved, and may be thrown down by the proper precipitants. These earthy salts are four in number: 1. Phosphate of lime, which constitutes by far the greatest part of the whole. 2. Carbonate of lime. 3. Phosphate of magnesia, lately discovered by Fourcroy and Vauquelin. It occurs in the bones of all the inferior animals examined by these indefatigable chemists, but could not be detected in human bones. 4. Sulphate of lime, detected by Mr Hatchett in a very minute proportion.

To estimate these substances, calcined bones may be dissolved in nitric or muriatic acid. During the solution carbonic acid gas makes its escape §. Pure ammonia dropt into the solution throws down the phos-

---

\* The discoverer of this has not been completely ascertained. Scheele does not claim it in that paper; Bergman gives it to Gahn; but Orill affirms that it was made by Scheele.

† *Phil. Trans.* 1799.

‡ *Ann. de Chim.* xlvii. 224.

§ Hatchett, *Phil. Trans.* 1799, p. 327.



phate of lime and phosphate of magnesia in the state of a fine powder, readily soluble without effervescence in nitric and muriatic acids. Nitrate of barytes afterwards causes a small precipitate insoluble in muriatic acid, and therefore consisting of sulphate of barytes. Its weight indicates the quantity of sulphuric acid in bones, from which the sulphate of lime which they contain may be estimated \*. Carbonate of ammonia now throws down pure carbonate of lime †. These three constituents were found by Hatchett in all the bones of quadrupeds and fish which he examined. The carbonate scarcely exceeds the fifth part of the phosphate, and the proportion of sulphate is still smaller. As the proportion of phosphate of lime varies not only in different animals, but even in different bones of the same animal, and even in the same bone of different ages, no precise numbers can be given. To detect and estimate the phosphate of magnesia, Fourcroy and Vauquelin employed the following simple method: The bones, previously calcined and reduced to powder, were treated with their own weight of sulphuric acid, and the mixture left to macerate for five or six days. It was then diluted with water,edulcorated, and filtered. The filtered liquid was mixed with an excess of ammonia, which threw down a mixture of phosphate of lime and

---

\* Hatchett, *Phil. Trans.* 1799, p. 327. The process described in the text was that employed by Mr Hatchett. As the bones which he examined were doubtless those belonging to the inferior animals, a little phosphate of magnesia-and-ammonia would probably remain after the liquid had been precipitated by ammonia. It is possible that the precipitate obtained with nitrate of barytes may be owing to the presence of this salt, and not to sulphate of lime.

† Hatchett, *Phil. Trans.* 1799, p. 327.



Book V.

ammonio-phosphate of magnesia. This precipitate is boiled in potash, which decomposes the magnesian salt, and leaves a mixture of magnesia and phosphate of lime. This mixture is treated with boiling acetous acid, which dissolves the magnesia, and leaves the phosphate of lime. The acetate of magnesia is decomposed by carbonate of soda, and the carbonate of magnesia obtained is dissolved in sulphuric acid \*.

2. Fat.

2. The proportion of fat contained in bones is various. By breaking bones in small pieces, and boiling them for some time in water, Mr Proust obtained their fat swimming on the surface of the liquid. It weighed, he says, one-fourth of the weight of the bones employed †. This proportion appears excessive, and can scarcely be accounted for without supposing that the fat still retained water.

3. Gelatine.

3. The gelatine is separated by the same means as the fat, by breaking the bones in pieces and boiling them long enough in water. The water dissolves the gelatine, and gelatinizes when sufficiently concentrated. Hence the importance of bones in making portable soups, the basis of which is concrete gelatine, and likewise in making glue. By this process Proust obtained from powdered bones about  $\frac{1}{8}$ th of their weight of gelatine. This celebrated chemist has been at considerable pains to point out the advantage of employing powdered bones in the preparation of soups and broths; and Cadet de Vaux has lately published a set of experiments to show, that from bones thus powdered as much good soup may be obtained as from five times

\* *Ann. de Chim.* xlvii. 247.† *Journ. de Phys.* lii. 257

their weight of meat \*. But when Dr Young repeated his improbable experiment it did not succeed †.

Chap. II.

4. When bones are deprived of their gelatine by boiling them in water, and of their earthy salts by steeping them in diluted acids, there remains a soft white elastic substance, possessing the figure of the bones, and known by the name of *cartilage*. From the experiments of Hatchett, it appears that this substance has the properties of coagulated albumen. Like that substance, it becomes brittle and semitransparent when dried, is readily soluble in hot nitric acid, is converted into gelatine by the action of diluted nitric acid; for it is soluble in hot water, and gelatinises on cooling, and ammonia dissolves it and assumes a deep orange colour. Like coagulated albumen, it forms an animal soap with fixed alkalis ‡.

4. Cartilage.

This cartilaginous substance is the portion of the bone first formed. Hence the softness of these parts at first. The phosphate of lime is afterwards gradually deposited, and gives the bone the requisite firmness. The gelatine and fat, especially the first, gave the bone the requisite degree of toughness and strength; for when they are removed the bone becomes brittle. The relative proportion of phosphate of lime and cartilage differs exceedingly in different bones and in different animals.

The following Table, drawn up by Merat-Guillot §, exhibits a comparative view of the relative proportion

\* *Jour. de Chim.* iv. 95. *Jour. of the Royal Institut.* ii. 18.

† *Ibid.* p. 25.

‡ *Phil. Trans.* 1800.

§ *Ann. de Chim.* lxxiv. 71.

Book V.

of these ingredients in a variety of bones. The sulphate of lime which occurs only in a very small quantity, and also the phosphate of magnesia, have been confounded with phosphate of lime. By gelatine, I suppose, we must understand cartilage. The real gelatine is included more probably in the loss.

Table of the constituents of bones.

One hundred parts contain	Gelatine	Phosph. of lime.	Carb. of lime.	Loss.
Human bones from a burying ground	16	67	1.5	15.5
Do. dry, but not from under the earth	23	63	2	12
Bone of ox	3	93	2	2
— calf	25	54	trace	21
— horse	9	67.5	1.25	22.25
— sheep	16	70	0.5	13.5
— elk	1.5	90	1	7.5
— hog	17	52	1	30
— hare	9	85	1	5
— pullet	6	72	1.5	20.5
— pike	12	64	1	23
— carp	6	45	0.5	48.5
Horse teeth	12	85.5	0.25	2.25
Ivory	24	64	0.1	11.15
Hartshorn	27	57.5	1	14.5

Ox bones, according to the analysis of Fourcroy and Vauquelin, are composed of

51.0 solid gelatine

37.7 phosphate of lime

10.0 carbonate of lime

1.3 phosphate of magnesia

---

100.0 \*

---

\* *Ann. de Chim.* xlvii. 258.

From the calcined bones of horses and sheep, fowls, and fishes, they extracted about  $\frac{1}{18}$ th part of phosphate of magnesia. Chap. II.

The only bone hitherto observed altogether destitute of cartilage is the enamel of the teeth. When the raspings of bones are steeped in diluted acids, the cartilage alone remains undissolved. Now, when the raspings of enamel are treated in this manner, Mr Hatchett observed that the whole was dissolved without any residuum whatever\*. If we believe Fourcroy and Vauquelin, the enamel of the teeth is composed of Enamel.

72.9 phosphate of lime

27.1 gelatine and water

---

100.0 †

But the most complete analysis of teeth has been made by Mr Pepys, and his results agree exactly with those of Hatchett. He found the enamel of the teeth composed of.....

78 phosphate of lime

6 carbonate of lime

16 loss and water

---

100 ‡

It is exceedingly probable that part of this loss may have been owing to a portion of gelatine; for though enamel is destitute of cartilage, it is probably provided with gelatine. The nitric acid employed is known to be a good solvent of gelatine even when much diluted. The infusion of tan would have ascertained its presence.

---

\* *Phil. Trans.* 1799, p 328.

† *Mém. de l'Institut*, ii. 232.

‡ Fox on the Teeth, p. 96.



Book V. From the analysis of Mr Pepys, we learn that the teeth are composed as follows \* :

Analysis of  
teeth.

	Roots of the Teeth.	Teeth of Adults.	First Teeth of Children.
Phosphate of lime	58	64	62
Carbonate of lime	4	6	6
Cartilage	28	20	20
Loss	10	10	12
Total	100	100	100

From this analysis, we see that teeth contain more phosphate and less cartilage than bone, and enamel more phosphate than teeth.

Fossil  
bones.

Mr Hatchett examined likewise *fossil* bones from the rock of Gibraltar. He found them to consist of phosphate of lime without any cartilage or soft animal part. Their interstices were filled with carbonate of lime. Hence they resemble exactly bones that have been burnt. They must, then, have been acted on by some foreign agent ; for putrefaction, or lying in the earth, does not soon destroy the cartilaginous part of bones. On putting a human os humeri, brought from Hythe in Kent, and said to have been taken from a Saxon tomb, into muriatic acid, he found the cartilaginous residuum nearly as complete as in a recent bone. From the recent experiments of Morichini †, Klaproth ‡, and Fourcroy and Vauquelin §, we learn that fossil ivory and teeth of animals frequently contain a portion of fluo-

\* Fox on the Teeth, p. 96.

† Gehlen's Jour. iii. 625.

‡ Phil. Mag. xxiii. 265.

§ Phil. Mag. xxv. 267.

of lime. Morichini and Gay Lussac endeavoured to prove that this salt existed even in recent ivory, and that the enamel of the teeth was almost entirely composed of it\*. But the experiments of Wollaston, Brande†, Fourcroy, and Vauquelin‡, have shown that there does not exist any sensible portion of fluoric acid in these substances while recent. Berzelius, however, has recently announced that he separated 3 *per cent.* of fluuate of lime from fresh teeth, and that he has detected it also in bones, nearly in the same proportion. He even affirms that it exists in urine§. And as his experiments appear to have been made with considerable care, it is probable that the results which he obtained are correct||.

There is reason to conclude, from the recent experiments of Bouillon La Grange, that the blue-coloured mineral called *torquoise* is a species of fossil bone, and that it owes its colour to the presence of some phosphate of iron¶.

## II. SHELLS.

UNDER the name of *shells* I include all the bony coverings of the different species of shell fish. Egg shells, also, from the similarity of their texture, belong to the same head. For almost all the knowledge of these substances that we possess, we are indebted to the late

\* *Phil. Mag.* xiii. 265.

† *Nicholson's Jour.* xiii. 216.

‡ *Phil. Mag.* xiv. 266.

§ *Gehlen's Jour.* vi. 591.

|| His experiments will be found in *Gehlen's Jour.* Second Series, lib. 2. There is an abstract of them in *Ann. de Chim.* lxi. 256.

¶ *Phil. Mag.* xvi. 220.

Book V.

important dissertations of Mr Hatchett. A few detached facts, indeed, had been observed by other chemists; but his experiments gave us a systematic view of the constituents of the whole class.

Shells, like bones, consist of calcareous salts united to a soft animal matter; but in them the lime is united chiefly to carbonic acid, whereas in bones it is united to phosphoric acid. In shells the predominating ingredient is carbonate of lime; whereas in bones it is phosphate of lime. This constitutes the characteristic difference in their composition.

Divided  
into two  
classes.

Mr Hatchett has divided shells into two classes. The first are usually of a compact texture, resemble porcelain, and have an enamelled surface, often finely variegated. The shells belonging to this class have been distinguished by the name of *porcelaneous shells*. To this class belong the various species of *veluta*, *cypræa*, &c. The shells belonging to the second class are usually covered with a strong epidermis, below which lies the shell in layers, and composed entirely of the substance well known by the name of *mother-of-pearl*\*. They have been distinguished by the name of *mother-of-pearl shells*. The *shell* of the *fresh water muscle*, the *halotis iris*, the *turbo elevarius*, are examples of such shells. The shells of the first of these classes contain a very small portion of soft animal matter; those of the second contain a very large proportion. Hence we see that they are extremely different in their composition.

\* Harissant, *Mém. Par.* 1766, p. 22.—Hatchett, *Phil. Trans.* 1796, p. 327.

1. Porcelaneous shells, when exposed to a red heat, crackle and lose the colour of their enamelled surface. They emit no smoke or smell; their figure continues unaltered, their colour becomes opaque white, tinged partially with pale grey. They dissolve when fresh with effervescence in acids, and without leaving any residue; but if they have been burnt their remains always a little charcoal. The solution is transparent, gives no precipitate with ammonia or acetate of lead; of course it contains no sensible portion of phosphate or sulphate of lime. Carbonate of ammonia throws down an abundant precipitate of carbonate of lime. Porcelaneous shells, then, consist of carbonate of lime cemented together by a small portion of an animal matter, which is soluble in acids, and therefore resembles gelatine\*.

Chap. II.

1. Porcelaneous.

Composed of carbonate of lime and a little jelly.

Patellæ from Madeira, examined by Mr Hatchett, were found, like the porcelaneous shells, to consist of carbonate of lime; but when exposed to a red heat they emitted a smell like horn; and when dissolved in acids a semiliquid gelatinous matter was left behind. They contain therefore less carbonate of lime and more gelatine, which is of a more viscid nature than that of porcelaneous shells.

Patellæ

2. Mother-of-pearl shells when exposed to a red heat crackle, blacken, and emit a strong fetid odour. They exfoliate, and become partly dark grey, partly a fine white. When immersed in acids they effervesce at first strongly; but gradually more and more feebly, till at last the emission of air-bubbles is scarcely perceptible.

2. Mother-of-pearl.

\* Hatchett, *Phil. Trans.* 1799, p. 317.



Book V.

Of mem-  
brane and  
carbonate of  
lime.

The acids take up only lime, and leave a number of thin membranous substances, which still retain the form of the shell. From Mr Hatchett's experiments, we learn that these membranes have the properties of coagulated albumen. Mother-of-pearl shells, then, are composed of alternate layers of coagulated albumen and carbonate of lime, beginning with the epidermis, and ending with the last formed membrane. The animals which inhabit these shells increase their habitation by the addition of a stratum of carbonate of lime, secured by a new membrane; and as every additional stratum exceeds in extent that which was previously formed, the shell becomes stronger as it becomes larger \*.

Though this in general is the structure of the mother-of-pearl shells, yet there is a considerable difference between the proportion of the component parts and the consistency of the albuminous part. Some of them, as the common oyster shell, approach nearly to the patella, the albuminous portion being small, and its consistence nearly gelatinous; while in others, as the *balotis iris*, the *turbo alcaeus*, the real mother-of-pearl, and a species of fresh water muscle analysed by Hatchett, the membranes are distinct, thin, compact, and semitransparent†.

Mother-of-pearl contains

66 carbonate of lime

24 membrane

---

100 †

Pearl.

*Pearl*, a well known globular concretion which is formed in some of these shells, resembles them exactly

\* Hatchett, *Phil. Trans.*, 1799, p. 317.

† Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

† Ibid.

in its structure and composition. It is a beautiful substance of a bluish white colour, iridescent, and brilliant. It is composed of concentric and alternate coats of thin membrane and carbonate of lime. Their iridescence is obviously the consequence of the lamellated structure\*.

Mr Hatchett found that what is called the *bone* of the *cuttle fish* is exactly similar to mother-of-pearl shells in its composition.

Bone of the  
cuttle fish.

From the comparative analysis of shells and bones, Mr Hatchett was induced to compare them together, and has shown that porcelaneous shells bear a striking resemblance to enamel of teeth; while mother-of-pearl shells bear the same resemblance to the substance of teeth or bone: with this difference, that in enamel and bone the earthy salt is phosphate of lime, whereas in shells it is pure carbonate of lime.

### III. CRUSTS.

By crusts we understand those bony coverings of which the whole external surface of crabs, lobsters, and other similar sea animals are composed. Mr Hatchett found them composed of three ingredients: 1. A cartilaginous substance, possessing the properties of coagulated albumen; 2. Carbonate of lime; 3. Phosphate of lime. By the presence of this last substance they are essentially distinguished from shells, and by the great excess of carbonate of lime above the phosphate they are equally distinguished from bones. Thus the

Constitu-  
ents.

\* Hatchett, *Phil. Trans.* 1799.

Book V.  
Between  
shells and  
bones.

crusts lie intermediate between bones and shells, partaking of the properties and constitution of each. The shells of the eggs of fowls must be referred likewise to the class of crusts, since they contain both phosphate and carbonate of lime. The animal cement in them, however, is much smaller in quantity. From the experiments of Berniard and Hatchett, it is extremely probable that the shells of snails are composed likewise of the same ingredients, phosphate of lime having been detected in them by these chemists.

Mr Hatchett examined the crusts of crabs, lobsters, prawns, and cray fish. When immersed in diluted nitric acid these crusts effervesced a little, and gradually assumed the form of a yellowish-white soft elastic cartilage, retaining the form of the crust. The solution yielded a precipitate to acetate of lead, and ammonia threw down phosphate of lime. Carbonate of ammonia threw down a much more copious precipitate of carbonate of lime. On examining the crust which covers different species of *echini*, Mr Hatchett found it to correspond with the other crusts in its composition. Some species of star-fish yielded phosphate of lime, others none: hence the covering of that genus of animals seems to be intermediate between shell and crust.

Analysis.

With these observations of Mr Hatchett the analysis of Merat-Guillot corresponds. From lobster crust he obtained .....

60	carbonate of lime
14	phosphate of lime
26	cartilage
100	*



One hundred parts of cray fish crust contain

Chap. II.

60 carbonate of lime

12 phosphate of lime

28 cartilage

---

100 \*

One hundred parts of hens egg-shells contain

Egg-shells.

89.6 carbonate of lime

5.7 phosphate of lime

4.7 animal matter

---

100.0 †

#### IV. ZOOPTHITES.

MANY of the substances called *zoophites* have the hardness and appearance of shell or bone, and may therefore be included among them without impropriety. Others, indeed, are soft, and belong rather to the class of membrane or horn; but of these very few only have been examined. Indeed scarcely any chemical experiments have been published on these interesting subjects, if we except the admirable dissertation by Hatchett in the Philosophical Transactions for 1800, which has been so often quoted. From this dissertation, and from a few experiments of Merat-Guillot, we learn that the hard zoophites are composed chiefly of three ingredients: 1. An animal substance of the nature of coagulated albumen, varying in consistency; sometimes

Composition.

---

\* Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

† Vauquelin, *Ibid.* xxix. 6.



## Book V.

being gelatinous and almost liquid, at others of the consistency of cartilage. 2. Carbonate of lime. 3. Phosphate of lime.

Divided  
into four  
classes.

In some zoophites the animal matter is very scanty, and phosphate of lime wanting altogether; in others the animal matter is abundant, and the earthy salt pure carbonate of lime; while in others the animal matter is abundant, and the hardening salt a mixture of carbonate of lime and phosphate of lime; and there is a fourth class almost destitute of earthy salts altogether. Thus there are four classes of zoophites; the first resemble porcelainous shells, the second resemble mother-of-pearl shells, the third resemble crusts, and the fourth horn.

1. Composed of carbonate of lime and jelly.

1. When the *madrepora virginea* is immersed in diluted nitric acid it effervesces strongly, and is soon dissolved. A few gelatinous particles float in the solution, which is otherwise transparent and colourless. Ammonia precipitates nothing; but its carbonate throws down abundance of carbonate of lime. It is composed, then, of carbonate of lime and a little animal matter. The following zoophites yield nearly the same results:

*Madrepora muricata*  
..... *labyrinthica*  
*Millepora cerulea*  
..... *alcicornis*  
*Tubipora musica*.

2. Of carbonate of lime and membrane.

2. When the *madrepora ramea* is plunged into weak nitric acid, an effervescence is equally produced; but after all the soluble part is taken up, there remains a membrane which retains completely the original shape of the madrepor. The substance taken up is pure

lime. Hence this madrepor is composed of carbonate of lime, and a membranaceous substance which, as in mother-of-pearl shells, retains the figure of the madrepor. The following zoophites yield nearly the same results :

*Madrepora fascicularis*  
*Millepora cellulosa*  
 ..... *fascialis*  
 ..... *truncata*  
*Iris hippuris*

The following substances, analysed by Merat-Guillot, belong to this class from their composition, though it is difficult to say what are the species of zoophites which were analysed. By *red coral* he probably meant the *gorgonia nobilis*, though that substance is known, from Hatchett's analysis, to contain also some phosphate.

	White coral.	Red coral.	Articulated coralline.
Carbonate of lime..	50	53.5	49
Animal matter....	50	46.5	51
	100	100.0	100 *

3. When the *madrepora polymorpha* is steeped in weak nitric acid, its shape continues unchanged ; there remaining a tough membranaceous substance of a white colour and opaque, filled with a transparent jelly. The acid solution yields a slight precipitate of phosphate of lime when treated with ammonia, and carbonate of ammonia throws down a copious precipitate of carbonate

3. Of membrane; carbonate, and phosphate.

\* Merat-Guillot, *Ann. de Chim.* xxxiv. 71.

Book V.

of lime. It is composed therefore of animal substance, partly in the state of jelly, partly in that of membrane, and hardened by carbonate of lime together with a little phosphate of lime.

*Flustra foliacea*, treated in the same manner, left a finely reticulated membrane, which possessed the properties of coagulated albumen. The solution contained a little phosphate of lime, and yielded abundance of carbonate of lime when treated with the alkaline carbonates. The *coralina opuntia*, treated in the same manner, yielded the same constituents; with this difference, that no phosphate of lime could be detected in the fresh coralline, but the solution of burnt coralline yielded traces of it. The *iris ochracea* exhibits the same phenomena, and is formed of the same constituents. When dissolved in weak nitric acid, its colouring matter falls in the state of a fine red powder, neither soluble in nitric nor muriatic acid, nor changed by them: whereas the tinging matter of the *tubipora musica* is destroyed by these acids. The branches of this iris are divided by a series of knots. These knots are cartilaginous bodies connected together by a membranous coat. Within this coat there is a conical cavity filled with the earthy or coralline matter; so that, in the recent state, the branches of the iris are capable of considerable motion, the knots answering the purpose of joints.

When the *gorgonia nobilis*, or red coral, is immersed in weak nitric acid, its colouring matter is destroyed, an effervescence takes place, and the calcareous part is dissolved. There remains an external tubulated membrane of a yellow colour, inclosing a transparent gelatinous substance. The solution yields only carbonate

of lime : but when red coral is heated to redness, and then dissolved, the solution yields a little phosphate of lime also. Red coral is composed of two parts : an internal stem, composed of gelatinous matter and carbonate of lime ; and an external covering or cortex, consisting of membrane hardened by the calcareous salts, and both coloured by some unknown substance.

The *gorgonia ceratophyta* likewise consists of a stem and cortex. The stem is composed of cartilage, hardened chiefly by phosphate of lime, and containing little carbonate of lime ; but the cortex consists of membrane hardened almost entirely by carbonate of lime. The *gorgonia flabellum* is almost exactly similar. The cortex of the *gorgonia suberosa* yielded gelatine to boiling water ; when steeped in acids, it left a soft yellowish membrane, and the acid had taken up a little phosphate and a large portion of carbonate of lime. The stem contained scarcely any earthy salt. When burnt, it left a little phosphate of lime. To water it yielded a little gelatine ; but it consisted chiefly of a horny substance, analogous to coagulated albumen. The *gorgonia setosa* and *pectinata* exhibited the same phenomena.

4. *Gorgonia antiphates*, like the other species of *gorgonia*, has a horny stem, but it is destitute of a cortex. To boiling water it gives out some gelatine. When steeped in nitric acid it becomes soft, and exhibits concentric coats of thin opaque brown membranes, of a ligneous aspect. It contains no earthy salt. With potash it forms an animal soap, and possesses nearly the properties of horn.

4. Chiefly  
of mem-  
brane.

The stems of the *gorgonia umbraculum* and *verrucosa* resemble that of the *gorgonia antiphates* ; but these are



Book V.

both provided with a cortex composed of membrane and carbonate of lime.

The *antiphates ulex* and *myriophylla* resemble almost exactly the horny stem of the *gorgonia antiphates*.

Mr Hatchett analysed many species of sponges, but found them all similar in their composition. The *spongia cancellata*, *oculata*, *infundibuliformis*, *palmata*, and *efficalis*, may be mentioned as specimens. They consist of gelatine, which they gradually give out to water, and a thin brittle membranous substance, which possesses the properties of coagulated albumen. Hence the effect of acids and alkalies on them.

The *alcyonium ficus*, *asbestinum*, and *arboreum*, resemble very much the cortex of the *gorgonia suberosa* in their composition. They yield a little gelatine to water. In nitric acid they soften, and appear membranous. The acid takes up the carbonate of lime, and likewise a little phosphate, at least when the substance has been previously heated to redness.

Such is an abstract of Mr Hatchett's instructive analysis of the zoophytes.

---

## SECT. II.

### OF HORNS, NAILS, AND SCALES.

In the last Section I treated of those hard parts of animals which were inflexible, softened by heat, and which consisted of calcareous salts; but there

parts which possess considerable elasticity, which are softened by heat, and which contain but a very small portion of calcareous matter. This set comprehends the substances well known under the names of *horn*, *nails*, and *scales*. The fourth class of zoophytes ought, in strict propriety, to be joined to them; but in the present state of our knowledge I thought it better to give a view of all that is known of the zoophytes in one place.

Almost all that we know of these bodies has been discovered by Mr Hatchett. Many experiments, indeed, had been made by preceding chemists; but not of such a nature as to throw much light upon their composition.

1. *Horns* are well known substances that are attached to the foreheads of oxen, sheep, and various other animals. They are not very hard, as they may be easily cut with a knife or rasped with a file; but they are so tough as not to be capable of being pounded in a mortar. When in thin plates they have a degree of transparency, and have been sometimes substituted for glass in windows. When heated sufficiently they become very soft and flexible, so that their shape may be altered considerably. Hence they may be gradually squeezed into a mould, and wrought into various forms, as is well known. When strongly heated in a Papin's digester, they are said to be converted into a gelatinous mass, which possesses the properties of gelatine.

The quantity of earthy matter which they contain is exceedingly small. Mr Hatchett burnt 500 grains of ox horn. The residuum was only 1.5 grain, and the half of this was phosphate of lime. Seventy-grains of the horn of the chamois left only 0.5

Composed  
of mem-  
brane.

## Book V.

of residue of which less than the half was phosphate of lime\*. They consist chiefly of a membranous substance, which possesses the properties of coagulated albumen; and probably they contain also a little gelatine. Hence we see the reason of the products that are obtained when these substances are subjected to distillation.

The horns of the hart and buck must, however, be excepted. From the experiments of Scheele and Rouelle, together with those of Hatchett, we know that these substances possess exactly the properties of bone, and are composed of the same constituents, excepting only that the proportion of cartilage is greater. They are intermediate, then, between bone and horn. The same remarks apply to a fossil horn found in France and lately analysed by Braconnot. He found it composed of

Siliceous sand.....	4.0
Gelatine.....	4.6
Bitumen.....	4.4
Oxide of iron.....	0.5
Alumina .....	0.7
Phosphate of magnesia.....	1.0
Water.....	11.0
Carbonate of lime.....	4.5
Phosphate of lime.....	69.3

---

100.0†

## Nails.

2. The *nails*, which cover the extremities of the fingers, are attached to the epidermis, and come off along with it. Mr Hatchett has ascertained that they are

---

\* *Phil. Trans.* 1779, p. 332.

† Gehlen's *Journ.* 3d Series, vol. 25



composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphate of lime. Water softens but does not dissolve them; but they are readily dissolved and decomposed by concentrated acids and alkalies. Hence it appears that nails agree with horn in their nature and composition. Under the head of nails must be comprehended the talons and claws of the inferior animals, and likewise their hoofs, which differ in no respect from horn.

The substance called tortoise-shell is very different from shells in its composition, and approaches much nearer to the nature of *nail*; for that reason I have placed it here. When long macerated in nitric acid, it softens, and appears to be composed of membranes laid over each other, and possessing the properties of coagulated albumen. When burnt, 500 grains of it yield three of earthy matter, consisting of phosphate of lime and soda, with a little iron \*.

Tortoise-shell.

3. The *scales* of animals are of two kinds; some, as those of serpents and other amphibious animals, have a striking resemblance to horn; while those of fish bear a greater resemblance to mother-of-pearl. The composition of these two kinds of shells is very different.

Scales.

The scales of fish, as had been observed by Lewenhoeck, are composed of different membranous laminæ. When immersed for four or five hours in nitric acid, they become transparent, and perfectly membranaceous. The acid, when saturated with ammonia, gives a copious precipitate of phosphate of lime †. Hence they are

1. Of fish.

Composed of membrane and phosphate.

\* Hatchett, *Phil. Trans.* 1799, p. 352.† *Ibid.*



parts. Of these, the muscles naturally claim our attention in the first place, as being the most important.

Chap. II.

The muscular parts of animals are known in common language by the name of *flesh*. They constitute a considerable proportion of the food of man.

Muscular flesh is composed of a great number of fibres or threads, commonly of a reddish or whitish colour; but its appearance is too well known to require any description. Hitherto it has not been subjected to any accurate chemical analysis. Mr Thouvenel, indeed, has published a very valuable dissertation on the subject; and it is to him that we are indebted for almost all the facts known concerning the composition of muscle. Some curious experiments have also been made by Fourcroy and Vauquelin; and Mr Hatchett has not neglected this part of the subject in his interesting dissertations on animal substances.

History.

It is scarcely possible to separate the muscle from all the other bodies with which it is mixed. A quantity of fat often adheres to it closely; blood pervades the whole of it: and every fibre is enveloped in a particular thin membranous matter, which anatomists distinguish by the name of *cellular substance*. The analysis of the muscle, then, cannot be supposed to exhibit an accurate view of the composition of pure muscular fibres, but only of muscular fibre not perfectly separated from other substances.

1. When a muscle is cut in small pieces, and well washed with water, the blood and other liquids contained in it are separated, and part of the muscular substance also is dissolved. The muscle, by this process, is converted into a white fibrous substance, still retaining the form of the original body. The water assumes

Action of cold water.

Book V.

the colour which results from mixing water with some blood. When heated it coagulates; brown flakes swim on the surface, consisting of albumen combined with the colouring matter of the blood: some fibrin likewise precipitates. If the evaporation be continued, more albumen precipitates, and at last the whole assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine thus formed, together with a little phosphate of soda and of ammonia, remains undissolved; but the alcohol dissolves a peculiar *extractive* matter, first observed by Thouvenel. This matter may be obtained by evaporating the alcohol to dryness. It has a reddish brown colour, a strong acid taste, and aromatic odour. It is soluble both in water and alcohol; and when its watery solution is very much concentrated, it assumes an acid and bitter taste. It swells upon hot coals, and melts, emitting an acid and penetrating smell. It attracts moisture from the air, and forms a saline efflorescence. In a hot atmosphere it becomes sour and putrefies. When distilled it yields an acid partly combined with ammonia.

Of hot water.

2. If the muscle, after being thus treated with cold water, be boiled for a sufficient time in water, an additional portion of the same substances are separated from it. Some albumen collects on the surface in the form of seum, accompanied with some melted fat. The water, when sufficiently concentrated by evaporation, assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine and phosphoric salts remain, while the extractive matter of Thouvenel is dissolved, and may be obtained by evaporating to dryness. It is by this process that it is procured in a sufficient quantity for examination, cold

water abstracting only a very small portion from the muscle. Chap. II.

3. The muscle, thus treated with water, is left in the state of grey fibres, insoluble in water, and becoming brittle when dry. This substance possesses all the properties of *fibrin*. Insoluble part.

4. From these facts, ascertained by Thouvenel and Fourcroy\*, it appears that the muscles are composed chiefly of fibrin, to which they owe their fibrous structure and their form, and that they contain also

- |               |                                     |               |
|---------------|-------------------------------------|---------------|
| 2. Albumen    | 5. Phosphate of soda                | Constituents. |
| 3. Gelatine   | 6. Phosphate of ammonia             |               |
| 4. Extractive | 7. Phosph. of lime and carb. of do. |               |

For the discovery of the last ingredients we are indebted to Mr Hatchett, who found that 500 parts of beef muscle left, after combustion, a residuum of 25.6 parts, consisting chiefly of these salts. When muscles are long boiled in water, Mr Hatchett found that the greater part of the phosphate of lime, as well as of the alkaline phosphates, was dissolved; for the muscle, after this treatment, when dissolved in nitric acid, yielded scarcely any phosphate of lime; whereas if it was dissolved directly in nitric acid, a precipitate of phosphate of lime was thrown down by ammonia. Hence it would appear, either that the phosphate of lime is united to gelatine, or that it is rendered soluble by means of it. The carbonate of lime still remains after the action of water, and is converted into oxalate when the muscle is treated with nitric acid.

Fourcroy and Vauquelin have likewise detected the

---

\* Fourcroy, ix. 242.



ese. Very little ammonia was given out during the process\*.

Chap. II.

1. The muscles of different animals differ exceedingly from each other in their appearance and properties, least as articles of food; but we know little of their chemical differences. The observations of Thouvenel were directed to that object, and they are imperfect. The flesh of the *ox* contains, according to him, the greatest quantity of insoluble matter, and leaves the latest residuum when dried; the flesh of the *calf* is more aqueous and mucous: the land and water *turtle* yields more matter to water than the muscle of the *ox*; Thouvenel ascribes the difference to foreign bodies, ligaments, &c. mixed with the muscle of the *turtle*: *It* yields to water a quantity of matter intermediate between that given by beef and veal: with them the muscles of *frogs*, *cray fish*, and *vipers*, agree nearly in this respect; but the muscles of fresh water fish, notwithstanding their softness, yield a considerably small proportion†.

Different kinds of muscles.

2. When meat is boiled, it is obvious that the gelatin, the extractive, and a portion of the salts, will be extracted, while the coagulated albumen and fibrin will remain in a solid state. Hence the flavour and the nourishing nature of soups derived from the extractive and gelatin. When meat is roasted, on the other hand, all these substances continue in it, and the taste and odour of the extractive is greatly heightened by the action of

\* *Mém. d'Arcueil*, i. 333.

Some experiments on the gizzards or muscular stomachs of fowls have been published by Bouillon La Grange. See *Nicholson's Journal*, 1806.



Book V.

the fire. Hence the superior flavour of roasted meat. Fourcroy supposes that the brown crust which forms on roasted meat is composed entirely of the extractive.

---

## SECT. IV.

### OF THE SKIN.

**T**HE skin is that strong thick covering which envelopes the whole external surface of animals. It is composed chiefly of two parts : a thin white elastic layer on the outside, which is called *epidermis* or *cuticle* ; and a much thicker layer, composed of a great many fibres closely interwoven, and disposed in different directions, this is called the *cutis*, or *true skin*. The *epidermis* is that part of the skin which is raised in blisters.

**Epidermis.** 1. The epidermis is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity.

It is totally insoluble in water and in alcohol. Fixed alkalies dissolve it completely, as does lime likewise, though slowly \*. Sulphuric and muriatic acids do not dissolve it, at least they have no sensible action on it for a considerable time ; but nitric acid soon deprives it of its elasticity, and causes it to fall to pieces †. It is well known that the living epidermis is tinged yellow.

---

\* Chaptal, *Ann. de Chim.* xxii. 221. But Davy could obtain no solution.

† Cruikshanks on *Insensible Perspiration*, p. 32.

is almost instantaneously by nitric acid; but this effect does not take place, at least so speedily, when the cuticle is plunged in nitric acid altogether\*.

If the cuticle be tinged with nitric acid, the application of ammonia to it is well known to give it instantaneously a deep orange colour. Now, as Hatchett has shown that this change is also produced upon coagulated albumen in the same circumstances, and as the epidermis resembles that substance in all the properties here detailed, it can scarcely be doubted that it is anything else than a peculiar modification of coagulated albumen.

2. The cutis is a thick dense membrane, composed of fibres interwoven like the texture of a hat. When it is macerated for some hours in water, and agitation and pressure are employed to accelerate the effect, the blood, and all the extraneous matter with which it was loaded, is separated from it, but its texture remains unaltered. By evaporating the water employed, a small quantity of gelatine may be obtained. No subsequent maceration in cold water has any farther effect. When distilled it yields the same products as fibrin. The concentrated alkalies dissolve it, converting it into oil and ammonia. Weak acids soften it, render it transparent, and at last dissolve it. Nitric acid converts it into oxalic acid and fat, while, at the same time, azotic gas and carbonic acid are emitted†. When heated it contracts, and then swells, exhales a fetid odour, and leaves a dense stercoral, difficult to incinerate. By spontaneous de-

Cutis.

\* Cruikshanks on *Invisible Perspiration*, p. 32.

† Fourcroy, ix. 254.

## Book V.

composition in water or moist earth, it is converted into a fatty matter and into ammonia, which compose a kind of soap\*. When allowed to remain long in water, it softens and putrefies, being converted into a kind of jelly. When long boiled in water it becomes gelatinous, and dissolves completely, constituting a viscid liquor, which, by proper evaporation, is converted into glue. Hence the cutis of animals is commonly employed in the manufacture of glue.

A species of  
gelatine.

From these facts the cutis appears to be a peculiar modification of gelatine enabled to resist the action of water, partly by the compactness of its texture, and partly by the viscosity of the gelatine of which it is formed; for those skins which dissolve most readily in boiling water afford the worst glue. Mr Hatchett has observed that the viscosity of the gelatine obtained from skins is nearly inversely as their flexibility, the supplest hides always yielding the weakest glue; but this glue is very soon obtained from them by hot water. The skin of the eel is very flexible, and affords very readily a great proportion of gelatine. The skin of the shark also readily yields abundance of gelatine; and the same remark applies to the skins of the hare, rabbit, calf, and ox; the difficulty of obtaining the glue and its goodness always increasing with the toughness of the hide. The hide of the rhinoceros, which is exceedingly strong and tough, far surpasses the rest in the difficulty of solution and in the goodness of its glue. When skins are boiled, they gradually swell and assume the appearance of horn: then they dissolve slowly.

---

\* Fourcroy, iz. 254.

3. It is from the skin or cutis of animals that leather is formed; and the goodness of the leather, or at least its strength, depends in some measure on the toughness of the hides. Those easily soluble, as seal skins, afford a weaker leather than those which are more difficultly soluble in water. The process by which the skins of animals are converted into leather is called *tanning*. It seems to have been known and practised in the earliest ages; but its nature was totally unknown till after the discovery of the *tanning principle* by Seguin. That chemist ascertained that leather is a compound of *tannin* and *skin*; that it is to the tannin that leather owes its insolubility and its power of resisting putrefaction. The subject has lately engaged the attention of Mr Davy, who has examined it with his usual ingenuity, and added several important facts to our former knowledge.

When skins are to be tanned, the first step of the process is to deprive them of their hair and cuticle. This is either done by steeping them in water till they begin to putrefy, or by steeping them in lime and water. The lime seems to combine with the cuticle, and to render it brittle and easily detachable from the hide. It produces the same effect upon the hair and the matter at its root\*. When the hides have been steeped for a sufficient time, they are taken out, the hair, cuticle, &c. scraped off, and then they are washed in water.

Preparation  
of the skins.

After this preliminary process, the skins are subjected to different treatment according to the kind of leather which is to be made.

The large and thick hides are introduced for a short

---

\* Davy, *Journal of the Royal Instit.* ii. 30.



Book V.

them into a strong infusion of bark. They are to be coloured. After this they are put into a slightly impregnated with sulphuric acid, a red acid evolved during the fermentation of tannin. This renders them harder and denser than they were before, and fits them for forming into leather. Davy thinks, that by this process a triple compound is formed of the skin, tan, and acid\*.

The light skins of cows, those of calves, and all skins, are steeped for some days in a liquor made by the infusion of pigeon's dung in water. This liquor is called the *grain*. By this process they are made thinner and softer and more proper for making into leather. Mr Davy considers the effect of this liquor to depend upon the fermentation which it undergoes for dung that has undergone fermentation does answer the purpose†.

After these preliminary processes, the skin is exposed to the action of the infusion of bark till they are converted into leather.

Process of tanning.

The infusion of oak bark contains two ingredients, namely, *tannin* and an *extractive*. The first is more soluble than the second. Hence, in saturated solution, there is a much greater proportion of tannin than of extractive; whereas in weak infusions the extractive has a greater proportion to the tannin. Mr Davy considers it as doubtful whether the infusion of oak bark contains any gallic acid. This chemist has ascertained, that the hides extract both the tannin and extractive from the

\* Davy, *Journals of the Royal Instit.* ii. 31.

† *Ibid.* p. 32.

‡ *Ibid.* p. 32.

on, and leave nothing behind but pure water, provided they be employed in sufficient quantity. Hence it is obvious, that both the tannin and extractive must enter into the composition of leather. The extractive renders the hide a brown colour, but does not render it insoluble in boiling water; the tannin renders it insoluble, but its colour continues whitish. Hence it is evident that the lightest kinds of leather contain little else but extractive, while the brown kinds contain both tannin and extractive. While the hides are allowed to remain in an infusion of bark, they combine of course with the tannin and extractive, and the new compound is leather. This is the reason of the increase of its weight.

Raw skins, and those hides which are prepared by the *traineur*, are first steeped in weak infusions of oak bark, and gradually removed to stronger and stronger, until they are completely impregnated, which takes up from two to four months. As the weak infusions contain a greater proportion of extractive, the consequence of this process is, that the skin combines in the first place with a portion of it, and afterwards with the tannin.

When saturated solutions of tannin are employed, leather is formed in a much shorter time. This is the process recommended by Seguin; but it has been observed, that leather tanned in this way is more brittle and more liable to crack than leather tanned in the former way. Hence it is likely, as Davy has observed, that the union of the extractive is requisite to form pliant and tough leather. Leather rapidly tanned must be as equable in its texture than leather slowly tanned, the surface must be saturated with tannin before the tannin has time to penetrate deep. Mr Davy has as-

Book V.

certained that skins, while tanning, seldom absorb more than  $\frac{1}{4}$  of their weight of vegetable matter.

Skins intended for sole leather are generally kept from the first in an infusion preserved nearly saturated by means of the strata of bark with which they alternate. The full impregnation requires from ten to eighteen months. It is likely, from this process, that sole leather contains a greater proportion of tannin than soft leather. While drying, it is smoothed with a rolling pin, and beat with a mallet, which must add considerably to its density\*.

Rete mucos.  
Follic.

4. As to the *rete mucosum*, or the mucous substance, situated between the cutis vera and epidermis, its composition cannot be determined with precision, because its quantity is too small to admit of examination. It is known that the black colour of negroes depends upon a black pigment, situated in this substance. Oxymuriatic acid deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that acid, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former intensity†. This experiment was first made by Dr Beddoes on the fingers of a negro‡.

\* See Davy on the Preparation of Skin for Tanning. Royal Instit. & p. 4.  
† Fourcroy, it. p. 259.      ‡ Beddoes on Facitious Aet. p. 25.



## SECT. V.

OF MEMBRANES, TENDONS, LIGAMENTS, AND  
GLANDS.

THESE substances have not hitherto been subjected to rigid chemical analysis. But from the properties which have been observed, they appear to have a closer resemblance to the skin than to any other animal substance.

1. The membranes are thin semitransparent bodies which envelope certain parts of the body, especially the viscera; such as, the dura and pia mater, the pleura, the peritoneum, the periosteum, &c. These substances are soft and pliable; when macerated in water, they swell, and become somewhat pulpy; and by continued decoction in hot water they are almost completely dissolved, and the solution concretes into gelatine. They are convertible of course into the same substance as the skin by decoction; hence we must consider their composition as similar. Like hides they may also be tanned and converted into leather. From the experiments of Mr Hatchett, it appears that they contain no phosphate of lime as a constituent part, and scarcely any saline ingredients; for when calcined they leave but a very inconsiderable residuum. Thus 250 grains of dog's bladder left only 0.02 grain of residuum\*.

Mem-  
branesResembles  
skin.

\* Phil. Trans. 1799, p. 333.



## Book V.

## Tendons.

2. The tendons are strong, pearl-coloured, brilliant bodies, which terminate the muscles, and attach them to the bones, and are known in common language by the name of *sineus*. When boiled they assume the form of a semitransparent gelatinous substance, of a pleasant taste, well known in boiled meat. If the decoction be continued they dissolve completely, and are converted into gelatine. From these facts we are authorized to conclude, that the composition of the tendons is similar to that of the membranes and cutis.

## Ligaments.

3. The ligaments are strong bands which bind the bones together at the different joints : they are fibrous substances, very dense and strong, and somewhat elastic. When boiled they yield a portion of gelatine, but they resist the action of water with great obstinacy, and after a great deal of boiling retain their form, and even their strength. The ligaments, then, differ essentially from the two last species. How far they resemble coagulated albumen remains to be ascertained. It is not unlikely that they will form a genus apart.

## Glands.

4. The glands are a set of bodies employed to form or to alter the different liquids which are employed for different purposes in the animal body. There are two sets of them : the *conglobate*, which are small, scattered in the course of the lymphatics ; and the *conglomerate*, such as the liver, kidneys, &c. Fourcroy supposes the first of these to be composed of gelatine ; but this is not very probable. The structure of the large glands has been examined by anatomists with great care ; but we are still ignorant of their composition. Indeed the present state of chemistry scarcely admits of an accurate analysis of these complicated bodies.

---

 SECT. VI.

## OF THE BRAIN AND NERVES.

THE brain and nerves are the instruments of sensation, and even of motion ; for an animal loses the power of moving a part the instant that the nerves which enter it are cut.

The brain and nerves have a strong resemblance to each other ; and it is probable that they agree also in their composition. But hitherto no attempt has been made to analyse the nerves. The only chemists who have examined the nature of *brain* are Mr Thouret\* and Mr Fourcroy†.

The brain consists of two substances, which differ from each other somewhat in colour, but which, in other respects, seem to be of the same nature. The outermost matter, having some small resemblance in colour to wood-ashes, has been called the *cineritious* part ; the innermost has been called the *medullary* part.

Properties  
of brain.

Brain has a soft feel, not unlike that of soap ; its texture appears to be very close ; its specific gravity is greater than that of water.

When brain is kept in close vessels so that the external air is excluded, it remains for a long time unaltered. Fourcroy filled a glass vessel almost completely with pieces of brain, and attached it to a pneumatic appa-

---

\* Jour. de Phys. LXXVIII. 329.

† Ann. de Chim. XVI. 282.

Book V.

ratus; a few bubbles of carbonic acid gas appeared at first, but it remained above a year without undergoing any farther change\*.

This is very far from being the case with brain exposed to the atmosphere. In a few days (at the temperature of 60°) it exhales a most detestable odour, becomes acid, assumes a green colour, and very soon a great quantity of ammonia makes its appearance in it.

Action of  
cold water,

Cold water does not dissolve any part of the brain: but by trituration in a mortar it forms, with water, a whitish-coloured emulsion, which appears homogeneous, may be passed through a filter, and the brain does not precipitate by rest. When this emulsion is heated to 145°, a white coagulum is formed. The addition of a great quantity of water also causes a coagulum to appear, which swims on the surface, but the water still retains a milky colour. When sulphuric acid is dropped into the watery emulsion of brain, white flakes separate and swim on the surface, and the liquid becomes red. Nitric acid produces the same effects, only the liquid becomes yellow. Alcohol also separates a white coagulum from the emulsion, after it has been mixed with it for some hours. When nitric acid is added to the emulsion till it becomes slightly acid, a coagulum is also separated. This coagulum is of a white colour; it is insoluble in water and in alcohol. Heat softens, but does not melt it. When dried it becomes transparent, and breaks with a glassy fracture. It has therefore some resemblance to *albumen*†.

Of sulphu-  
ric acid.

When brain is triturated in a mortar with diluted

\* *Ann. de Chim.* xvi. 297.

† *Ibid.* p. 282.



sulphuric acid, part is dissolved; the rest may be separated, by filtration, in the form of a coagulum. The acid liquor is colourless. By evaporation, the liquid becomes black, sulphurous acid is exhaled, and crystals appear; and when evaporated to dryness, a black mass remains behind. When this mass is diluted with water, a quantity of charcoal separates, and the water remains clear: The brain is completely decomposed, a quantity of ammonia combines with the acid and forms sulphate of ammonia, while charcoal is precipitated. The water, by evaporation and treatment with alcohol, yields sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia. Brain therefore contains

Phosphate of lime

..... soda

..... ammonia.

Traces also of sulphate of lime can be discovered in it. The quantity of these salts is very small; altogether they do not amount to  $\frac{1}{11}$ th part\*.

Diluted nitric acid, when triturated with brain, likewise dissolves a part, and coagulates the rest. The solution is transparent. When evaporated till the acid becomes concentrated, carbonic acid gas and nitrous gas are disengaged; an effervescence takes place, white fumes appear, an immense quantity of ammonia is disengaged, a bulky charcoal remains mixed with a considerable quantity of oxalic acid†.

Of nitric acid,

When brain is gradually evaporated to dryness by the heat of a water bath, a portion of transparent liquid

\* *Ann. de Chim.* xvi. 283.

† *Ibid.* 307.



separated it first from the rest, and the residuum, when ~~completely~~ dry, acquires a brown colour; its weight amounts to about one-fourth of the fresh brain. It may still be formed into an emulsion with water, but very soon separates again spontaneously.

When alcohol is repeatedly boiled upon this dried residuum till it ceases to have any more action, it dissolves about five-eighths of the whole. When this alcohol cools, it deposits a yellowish white substance, composed of brilliant plates. When kneaded together by the fingers, it assumes the appearance of a decile paste: at the temperature of boiling water it becomes soft, and when the heat is increased it blackens, exhales empyreumatic and ammoniacal fumes, and leaves behind it a charry matter\*. When the alcohol is evaporated, it deposits a yellowish black matter, which reddens paper tinged with turnsole, and readily diffuses itself through water†.

Pure concentrated potash dissolves brain, disengaging a great quantity of ammonia.

These facts are sufficient to show us that, exclusive of the small proportion of saline ingredients, brain is composed of a peculiar matter, differing in many particulars from all other animal substances, but having a considerable resemblance in many of its properties to albumen. Brain has been compared to a soap; but it is plain that the resemblance is very faint, as scarcely any oily matter could be extracted from brain by Fourcroy, though he attempted it by all the contrivance which the present state of chemistry suggested; and the

\* *Ann. de Chim.* xvi. 313.

† *Ibid.* 317.

alkaline portion of it is a great deal too small to merit any attention. Chap. II.

---

## SECT. VII.

## MARROW.

THE hollows of the long bones are in living animals filled with a peculiar species of fat matter, to which the name of *marrow* has been given. In some bones this matter is a good deal mixed with blood, and has a red colour; in others, as the thigh bones, it is purer, and has a yellow colour. Various experiments on this matter were made by the older chemists, showing it to be analogous to animal fats\*, and pointing out some of its peculiarities. Berzelius has lately examined it in detail, and published the results of his experiments†. The marrow on which his trials were made was obtained from the thigh bone of an ox.

1. When marrow is digested in cold water it becomes lighter coloured, while the water acquires the colour which it would have received had it been digested on blood. When this water is boiled it becomes muddy, and a dark brown matter precipitates. This matter consists of coagulated albumen mixed with some phos-

Action of  
cold water.

---

\* Neumann's *Chemistry*, p. 360.

† Gehlen's *Jour.* Second Series, ii. 287.

## Book V.

phate of lime, and phosphate of iron. A small portion of a yellow coloured salt is dissolved by the action of alcohol or water. This matter separated from marrow by water, is obviously owing to the blood with which it was mixed. The quantity which Berzelius obtained from marrow amounted to  $\frac{1}{100}$ th part of the whole. The portion of it dissolved by water and alcohol consisted partly of gelatine and common salt, and partly of the peculiar extractive matter obtained by Thouvenel from the muscles of animals, and described in the Third Section of this Chapter. The proportion of these substances obtained by Berzelius from marrow, amounted to about  $\frac{1}{100}$ th part of the whole.

## Of hot water.

2. When marrow is boiled in water, the greatest part of it melts and swims upon the surface of the liquid. The water is at first muddy and milky, but becomes transparent on standing. When passed through the filter a substance is separated, which becomes greyish green, and semitransparent when dry. More of this matter precipitates when the liquid is evaporated. When the water is evaporated to dryness, a substance is obtained of a sharp aromatic taste like the marrow of roasted meat. These two substances consist chiefly of extractive, gelatine, and a peculiar substance which approaches the nature of albumen in its properties.

3. When marrow, thus purified, is melted in water and passed through a cloth, a quantity of blood vessels and skins remain upon the cloth, amounting to about  $\frac{1}{100}$ th part of the whole.

## Properties of pure marrow.

4. Marrow, thus freed from its impurities, has a white colour with a shade of blue; its taste is insipid and rather sweetish. It softens by the heat of the hand,



and melts when heated to  $113^{\circ}$  \*. When cooled slowly it crystallizes in sphericles like olive oil. It burns with a flame like tallow. When distilled it gives first a transparent fluid yellowish oil, accompanied by carbonic acid gas, water, and heavy inflammable air. Afterwards there comes over a white solid oil, accompanied by a less copious evolution of gaseous bodies, and which does not become dark coloured, as happens when tallow is distilled. This had already been observed by Neumann. This solid oil has a disagreeable smell, amounts to 0.8 of the marrow distilled, reddens vegetable blues, and when boiled in water gives out a portion of sebacic acid, which Berzelius considers as benzoic acid.

The empyreumatic oil combines readily with alkalies and their carbonates. With the latter it forms a snow white soap, insoluble in water, though it increases in bulk when placed in contact with that liquid. It combines also with the earths, and forms soaps likewise insoluble in water.

The water which comes over during the distillation of marrow is colourless, has a fetid and sour smell, and an empyreumatic taste. It contains a little acetic acid, empyreumatic oil, and probably benzoic acid; but exhibits no traces of ammonia.

The gaseous products amount to  $\frac{1}{10}$ th of the marrow distilled. They contain no sulphur nor phosphorus, and consist of carbonic acid and heavy inflammable air, which burns with a white flame, and seems to contain oil in solution.

---

\* Berzelius says at  $45^{\circ}$ . This is  $113^{\circ}$  Fahrenheit, if Celsius' thermometer be meant, as is probable. If it be Reaumur's, the melting point of marrow is  $133^{\circ}$  Fahrenheit.



## Book V.

The charry matter in the retort amounts to 0.05 of the marrow distilled. It is dark brown, heavy and brilliant. It is incinerated with difficulty, and leaves an ash consisting of phosphate of lime, carbonate of lime, and some soda.

## Action of acids.

5. Concentrated sulphuric acid dissolves marrow without the assistance of heat. The solution has the appearance of a brown syrup; and when the acid is diluted with water the marrow separates unaltered. When heat is applied, the acid decomposes the marrow and forms a resinous coal.

Diluted nitric acid digested in marrow, in a moderate heat, renders it yellow, and gives it more consistence, and the smell of old bones. Concentrated nitric acid dissolves marrow without the assistance of heat, and the marrow is not precipitated by the addition of water.

6. Marrow combines with alkalies and forms soap. Boiling alcohol and ether dissolve a small portion of it, which precipitates again as the solution cools.

## Constituents.

Marrow, from the thigh bone of an ox, was found by Berzelius to be composed of the following substances:

Pure marrow .....	0.98
Skins and blood vessels ...	0.01
Albumen	} ..... 0.03
Gelatine	
Extractive	
Peculiar matter	
Water	

---

1.00

From the preceding detail it appears, that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature. But

It differs considerably in its appearance in different parts of the body, owing chiefly, in all probability, to a greater or smaller mixture of blood. Chap. II.

---

## SECT. VIII.

### OF HAIR AND FEATHERS.

THESE substances cover different parts of animals, and are obviously intended by Nature to protect them from the cold. For this, their softness and pliability, and the slowness with which they conduct heat, render them peculiarly proper.

1. *Hair* is usually distinguished into various kinds, according to its size and appearance. The strongest and stiffest of all is called *bristle*; of this kind is the hair on the backs of hogs. When remarkably fine, soft, and pliable, it is called *wool*; and the finest of all is known by the name of *down*. But all these varieties resemble one another very closely in their composition. Varieties.

Hair appears to be a kind of tube covered with a cuticle. Its surface is not smooth, but either covered with scales or consisting of imbricated cones. Hence the roughness of its feel, and the disposition which it has to entangle itself, which has given origin to the processes of *felting* and *fulling*. It is constantly increasing in length, being protruded from the roots, and Properties.

Vol. V. M m

When the solution is filtered to get rid of this oil, the liquid which passes through is nearly colourless. Copious precipitates are formed in it by the infusion of nutgalls and oxymuriatic acid. Silver is blackened by it, and acetate of lead precipitated brown. Acids render it turbid, but the precipitate is redissolved by adding these liquids in excess. Though very much concentrated by evaporation, it does not concrete into a jelly.

Water containing only four *per cent.* of potash dissolves hair, while hydrosulphuret of ammonia is evolved. If the hair be black, a thick dark-coloured oil, with some sulphur and iron, remains undissolved; if the hair be red, there remains a yellow oil, with some sulphur and an atom or two of iron. When acids are dropt into this solution, they throw down a white matter soluble in an excess of acid.

Sulphuric and muriatic acids become red when first poured on hair, and gradually dissolve it. Nitric acid turns hair yellow and dissolves it, while an oil separates, which is red or black according to the colour of the hair dissolved. The solution yields a great deal of oxalic acid, and contains, besides, bitter principle, iron, and sulphuric acid. Oxymuriatic acid first whitens hair, and then reduces it to a substance of the consistence of turpentine, and partly soluble in alcohol.

When alcohol is digested on black hair, it extracts from it two kinds of oil. The first, which is white, subsides in white shining scales as the liquor cools; the second is obtained by evaporating the alcohol. It has a greyish green colour, and at last becomes solid. From red hair alcohol likewise separates two oils; the first white as from black hair, and the other as red as blood. When the red hair is deprived of this oil, it

Colouring  
matter.



Book V.

becomes of a chesnut colour. Hence its red colour is obviously owing to the red oil.

When hair is incinerated, it yields iron and manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and a considerable portion of silica. The ashes of red hair contain less iron and manganese: those of white hair still less; but in them we find magnesia, which is wanting in the other varieties of hair. The ashes of hair do not exceed 0.015 of the hair.

From the preceding experiments of Vauquelin, we learn that black hair is composed of the nine following substances:

Constituent parts.

1. An animal matter, constituting the greatest part
2. A white solid oil, small in quantity
3. A greyish green oil, more abundant
4. Iron; state unknown
5. Oxide of manganese
6. Phosphate of lime
7. Carbonate of lime, very scanty
8. Silica
9. Sulphur

The colouring matter of hair appears from Vauquelin's experiments to be an oil. The oil is blackish green in black hair, red in red hair, and white in white hair. Vauquelin supposes that sulphureted iron contributes to the colour of dark hair; and ascribes to the presence of an excess of sulphur the property which white and red hair have of becoming black with the oxides of the white metals. The sudden change of colour in hair from grief, he thinks, is owing to the evolution of an acid \*.

---

\* Nicholson's Jour. xv. 241.



Vauquelin considers the animal matter of which hair is chiefly composed as a variety of inspissated mucus; some of its properties, especially its copious precipitation by tannin, do not well agree with that supposed. It seems to approach more closely to coagulated albumen, as Hatchett has shown.

Wool has not yet been subjected to a rigid examination.

but from the experiments made on it by Berthollet there is reason to conclude that its chemical qualities do not differ much from those of hair. When grown upon the sheep it is enveloped in a kind of soapy matter, which protects it from the attack of insects, and which is afterwards removed by scouring. Vauquelin lately examined this matter, and found it to consist of the following ingredients: 1. A soap of potash; 2. Carbonate of potash; 3. A little acetate of potash; 4. Muriate of potash; 5. A very little muriate of potash; and, 6. Animal matter\*.

Feathers seem to possess very nearly the same properties with hair. Mr Hatchett has ascertained that they are composed chiefly of coagulated albumen. Though feathers were boiled for a long time in water, Mr Hatchett could observe no traces of gelatine.

\* *Ann. de Chim.* xlvii. 267.

Book V.

## SECT. IX.

## OF SILK.

Origin.

SILK is the production of different species of caterpillars. The *phalena bombyx* is most commonly propagated for that purpose in Europe; but the *phalena cecias* yields a greater quantity. A similar substance indeed is yielded by the greater number of the tribe of caterpillars. It is found inclosed in two small bags, from which it is protruded in fine threads, to serve the insect for a covering during its crystalis state. The webs of spiders are obviously of the same nature with silk; though their fibres, at least in this country, are finer and weaker. Reaumur and other naturalists ascertained, that the larger species of spiders spun cocoons sufficiently strong to be manufactured, and that the produce was neither inferior in beauty nor in strength to the silk of the silkworm. Attempts were made in consequence to establish a manufactory of this new kind of silk; but it was soon found that the spiders could not be made to work in concert. They attacked and devoured each other without mercy, till the whole colony was exterminated to a single individual.

History.

The silkworm is a native of China, and feeds on the leaves of the white mulberry. That industrious nation was acquainted with the manufacture of silk from the most remote ages; but it was scarcely known in Eu-

Spiders' web

before the time of Augustus. Its beauty attracted the attention of the luxurious Romans; and after the minute reign of Elagabalus, it became a common mode of dress. It was brought from China at an enormous expense, manufactured again by the Phenicians, sold at Rome for its weight of gold. In the reign of the Arsacidian this commerce was interrupted by the contests of the Scythian tribes, and all attempts to procure it failed, till two Persian monks had the address to convey some of the eggs of the insect from China to Constantinople, concealed in the hollow of a cane. They hatched, and the breed carefully propagated. This succeeded in 555; and some years after we find that the Greeks understood the art of procuring and manufacturing silk as well as the Orientals. Roger, king of Sicily, brought the manufacture to that island in 1130, secretly carrying off the weavers from Greece, and settling them in Sicily. From that island the art passed into Italy, and thence into France: and the revocation of the edict of Nantz established the manufactory of silk in Britain.

Silk, as spun by the animal, is in the state of fine threads, varying in colour from white to reddish yellow.

It is very elastic, and has considerable strength, to consider its small diameter. It is covered with a varnish, to which its elasticity is owing. This varnish is soluble in boiling water; but alcohol does not dissolve it. Hence it has been compared to a gum, though it approaches much nearer to gelatine; since Berzelius has shown that it is precipitated by tannin or by muriate of tin. It differs, however, from gelatine in several particulars. Alum throws it down of a dirty white, sulphate of copper of a dark brown, and

Varnish.



Book V.

sulphate of iron of a brown colour \*. When the water is evaporated, the varnish is obtained of a black colour, brittle, and of a shining fracture. Its weight is nearly one-third of the raw silk from which it was extracted. It may be separated from silk by soap as well as water, and the soap leys containing it soon putrefy †. Roard has lately published a set of experiments on this matter. It amounts to 29 *per cent.* of the silk. It is brittle and hard like resins; when pounded its colour is reddish yellow. It has the taste and odour of extractive. It does not melt when heated. It dissolves in five times its weight of water. The solution has a brown colour, but when diluted with water becomes golden yellow. When exposed to the air in that state it becomes greenish, is decomposed, and exhales the odour of putrid animal matter. The liquid froths like soap leys. Sulphuric and muriatic acids deepen its colour; nitric acid converts it into a fine yellow; sulphurous acid brightens the colour, and makes it greenish yellow. Alcohol scarcely acts upon it. Oxymuriatic acid throws down a copious white precipitate, which becomes reddish in the air, is no longer soluble in water, but is very soluble in alcohol. Alkalies produce no effect upon this substance. Infusion of nut-galls occasions a copious precipitate ‡. These properties show us that this substance is of a peculiar nature.

Resin.

Besides the varnish, silk contains another substance, to which it owes its yellow colour. This substance possesses the properties of *resin*. It is yellow, soluble in alcohol, and in a mixture of alcohol and muriatic a.

\* Berthollet.

† Ibid.

‡ *Ann. de Chim.* lxx. 52.



cid. Baumé has ascertained, that by this last mixture it may be separated completely, and the silk deprived of it assumes a fine white colour\*. This matter melts at  $86^{\circ}$ . Its colour is reddish brown when in lumps, but greenish yellow when divided. It has a strong smell, owing to a volatile oil which it contains. When exposed to the light it becomes white. It is insoluble in water but very soluble in alcohol, in the alkaline solutions and in soap†.

Roard has shown that raw silk contains also a portion of wax, which is dissolved by boiling alcohol, and by alkaline or soapy solutions. It is white and precipitates as the alcohol cools. Silk contains about  $\frac{1}{100}$ th of its weight of wax, while the resinous colouring matter amounts to about  $\frac{1}{100}$ th of its weight‡.

The properties of silk itself have been but imperfectly examined. It is not acted on by water or alcohol, has no taste, and is but imperfectly combustible; though fire rapidly blackens and decomposes it. When distilled, it yields, according to Neumann, an uncommonly great proportion of ammonia.

Properties  
of silk.

The fixed alkalies dissolve it by the assistance of heat; and it is not unlikely that they form with it an animal soap.

It is dissolved likewise by sulphuric and muriatic acids, and by nitric acid. By the action of this last acid, Berthollet obtained from silk some oxalic acid, and a fatty matter which swam on the surface of the solution. By a similar treatment, Welter obtained fine

\* *Ann. de Chim.* xvii. 156.

† Roard, *Ibid.* lxx. 61.

‡ *Ibid.*

Book V.

yellow crystals, very combustible, to which he gave the name of *yellow bitter principle*.

Silk is very little susceptible of putrefaction. Dr Wilson of Falkirk informs us, that a ribbon was lately found in the churchyard of that town wrapt round the bone of the arm. It was uninjured though it had lain eight years in the earth\*. We know, at the same time, that when silk is kept in a damp place it ~~rot~~ (to use the common language) in a much shorter period.

Spiders' web.

Cadet has lately published a chemical analysis of spiders' webs, the result of which, as these substances have a considerable analogy to silk, both in their properties and mode of being produced, may be mentioned here. He obtained from spiders' webs, by treating them with water and alcohol, and incineration, the following substances: 1. A brown extract soluble in water, and not altered by exposure to the air; 2. A resinous matter soluble in alcohol, and very deliquescent; 3. Alumina; 4. Sulphate of lime; 5. Carbonate of soda; 6. Muriate of soda; 7. Carbonate of lime; 8. Iron; 9. Silica†. He supposes, however, that some of the fixed matters obtained may have originated from accidental impurities mixed with the webs examined.

---

HAVING given the preceding account of the solids which compose animal bodies, I proceed next to the fluid which circulates through living bodies, namely *blood*; and to the various *secretions* formed from the

\* Nicholson's Jour. ii. 222.

† Ibid. xi. 294.

blood, either in order to answer some important purpose to the animal, or to be evacuated as useless, that the blood thus purified may be more proper for answering the ends for which it is destined. Many of these substances have been examined with more care by chemists than the animal solids.

## SECT. X.

### OF BLOOD.

**B**LOOD is a well-known fluid which circulates in the veins and arteries of the more perfect animals. It is of a red colour, has a considerable degree of consistency, and an unctuous feel, as if it contained a quantity of soap. Its taste is slightly saline, and it has a peculiar smell.

Properties  
of blood.

The specific gravity of human blood is, at a medium, 1.0527 \*. Mr Fourcroy found the specific gravity of bullock's blood, at the temperature of 60°, to be 1.056 †. The blood does not uniformly retain the same consistence in the same animal, and its consistence in different animals is very various. It is easy to see that its specific gravity must be equally various.

No substance has attracted a greater degree of attention than the blood. The number of philosophers who have devoted their time to develope its nature, and as-

\* Haller's *Physiology*, ii. 41.

† *Ann. de Chim.* vii. 147.

Book V.

certain its properties, is immense. It was not, however, till towards the middle of the eighteenth century that much progress was made in its chemical analysis\*. The prussic acid formed during its decomposition had been observed; Hales had measured the gases exhaled during its distillation; Menghini had demonstrated the presence of iron in it; and several curious observations had been made upon its coagulation. But Rouelle junior was the first chemist who published a tolerably precise analysis of it. Since that time much additional information has been acquired by the experiments of Bucquet, Fourcroy, Deyeux, Pärmentier, &c.

Spectro-  
scopic de-  
composition.

When blood, after being drawn from an animal, is allowed to remain for some time at rest, it very soon coagulates into a solid mass of the consistence of curdled milk. This mass gradually separates into two parts; one of which is fluid, and is called *serum*; the other, the coagulum, has been called *cruor*, because it alone retains the red colour which distinguishes blood. This separation is very similar to the separation of curdled milk into curds and whey.

The proportion between the *cruor* and *serum* of the blood varies much in different animals, and even in the same animal in different circumstances. The most common proportion is about one part of *cruor* to three parts of *serum*; but in many cases the *cruor* exceeds or falls short of this quantity; the limits of the ratios of these substances to each other appear, from a comparison of the conclusions of most of those who have written ac-

---

\* A very full account of every thing that had been done before that time may be found in the second volume of Haller's *Physiologia*.



exactly on the subject, to be 1 : 1 and 1 : 4 ; but the first case must be very rare indeed \*.

The cause of this spontaneous decomposition of blood has not hitherto been ascertained. The coagulation takes place equally in close vessels and in the open air, whether the blood be allowed to cool, or be kept at the temperature at which it is when it issues from the animal ; neither is the coagulation prevented by diluting it with water, as has been sufficiently proved by the experiments of Hewson, Hunter, Deyeux, and Parmentier.

1. The serum is of a light greenish yellow colour ; Serum it has the taste, smell, and feel of the blood, but its consistence is not so great. Its mean specific gravity is about 1.0287 †. It converts syrup of violets to a green, and therefore contains an alkali. On examination, Rouelle found that it owes this property to a portion of soda ‡. When heated to the temperature of 156° §, the serum coagulates, as Harvey first discovered ||. It coagulates also when boiling water is mixed with it ; but if serum be mixed with six parts of cold water, it does not coagulate by heat ¶. When thus coagulated, it has a greyish white colour, and is not unlike the boiled white of an egg \*\*. If the coagulum be cut into small pieces, a muddy fluid may be squeezed from it, which has been termed the *serosity*. After the separation of this fluid, if the residuum be carefully washed in boiling water and examined, it will be found

\* Haller's *Physiology*, ii. 47.

† Jurin, *Ibid.* p. 41.

‡ Dr Pearson considers the alkali in animal fluids as potash, and not soda.

§ Cullen.

|| *De Gener. Anim.* p. 161.

¶ Fourcroy, *Ann. de Chim.* vii. 152.

\*\* *Ibid.* 156.

- Book V.  
Contains albumen, to possess all the properties of coagulated *albumen*. The serum, therefore, contains a considerable proportion of albumen. Hence its coagulation by heat, and the other phenomena which albumen usually exhibits.
- Gelatine, If serum be diluted with six times its weight of water, and then boiled to coagulate the albumen, the liquid which remains after the separation of the coagulum, if it be gently evaporated till it becomes concentrated, and then be allowed to cool, assumes the form of a jelly, as was first observed by De Haen \*. Consequently it contains *gelatine* †.
- Sulphur, If the coagulated serum be heated in a silver vessel, the surface of the silver becomes black, being converted into a sulphuret. Hence it is evident that it contains sulphur ‡; and Proust has ascertained that it is combined with ammonia in the state of a hydrosulphuret.
- And salts. If serum be mixed with twice its weight of water, and, after coagulation by heat, the albumen be separated by filtration, and the liquid be slowly evaporated till it is considerably concentrated, a number of crystals are deposited when the liquid is left standing in a cool place. These crystals, first examined by Rouelle, consist of carbonate of soda, muriate of soda, besides phosphate of soda and phosphate of lime. The soda exists in the blood in a caustic state, and seems to be combined with the gelatine and albumen. The carbonic acid combines with it during evaporation.

---

\* Fourcroy, *Ann. de Chim.* vii. 157.

† Dr Bostock repeated this experiment without success; hence it is probable that blood contains no gelatine.

‡ Deyeux and Parmentier, *Jour. de Phys.* liv. 437.

Thus it appears that the serum of the blood contains albumen, gelatine, hydrosulphuret of ammonia, soda, muriate of soda, phosphate of soda, and phosphate of lime. These component parts account for the coagulation occasioned in the serum by acids and alcohol, and the precipitation produced by tannin, acetate of lead, and other metallic salts.

2. The cruor, or *clot* as it is sometimes called, is of a red colour, and possesses considerable consistence. Its mean specific gravity is about 1.245\*. If this cruor be washed carefully by letting a small jet of water fall upon it till the water runs off colourless, it is partly dissolved, and partly remains upon the searce. Thus it is separated into two portions: namely, 1. A white, solid, elastic substance, which has all the properties of *fibrin*; 2. The portion held in solution by the water, which consists of the colouring matter, not however in a state of purity, for it is impossible to separate the cruor completely from the serum.

Cruor contains fibrin,

We are indebted to Bucquet for the first precise set of experiments on this last watery solution. It is of a red colour. Bucquet proved that it contained albumen and iron. Menghini had ascertained, that if blood be evaporated to dryness by a gentle heat, a quantity of iron may be separated from it by the magnet. The quantity which he obtained was considerable; according to him, the blood of a healthy man contains above two ounces of it. Now, as neither the serum nor the fibrin extracted from the cruor contains iron, it follows of course, that the water holding the colouring matter in solution must contain the whole of that metal.

\* Jurin, Haller's *Physiology*, ii. 41.



Book V.

Albumen,

Soda.

This watery solution gives a green colour to syrup of violets. When exposed to the air, it gradually deposits flakes, which have the properties of albumen. When heated, a brown-coloured scum gathers on its surface. If it be evaporated to dryness, and then mixed with alcohol, a portion is dissolved, and the alcoholic solution yields by evaporation a residuum, which lathers like soap in water, and tinges vegetable blues green; the acids occasion a precipitate from its solution. This substance is a compound of albumen and soda. Thus we see that the watery solution contains albumen, iron, and soda.

Sub-phosphate of iron.

Fourcroy and Vauquelin have ascertained that the iron is combined with phosphoric acid, and in the state of sub-phosphate of iron; thus confirming an opinion which had been maintained by Sage, and announced as a fact by Gren. If the residuum obtained by evaporating the watery solution of the colouring matter of blood to dryness be burnt in a crucible, there will remain a deep red ferruginous substance, amounting to 0.045 of the blood employed. Nitric acid digested on this residuum dissolves a portion, which is phosphate of iron, and is precipitated white by ammonia, but assumes a red colour when treated with pure potash. When lime-water is poured into the potash employed, phosphate of lime precipitates. By this treatment they ascertained that  $\frac{1}{2}$ ths of the residuum consisted of sub-phosphate of iron. Now phosphate of iron is soluble in acids, but insoluble in water; when treated with pure alkalies, it loses a portion of its acid, assumes a red colour, and is converted into sub-phosphate. Hence it is evidently the soda of the blood which reduces it to that state, or at least maintains it in that state. Sub-



phosphate of iron readily dissolves in albumen and in serum\*.

3. When new-drawn blood is stirred briskly round with a stick or the hand, the whole of the fibrin collects together upon the stick, and in this manner may be separated altogether from the rest of the blood. The red globules, in this case, remain behind in the serum. It is in this manner that the blood is prepared for the different purposes to which it is put; as clarifying sugar, making puddings, &c. After the fibrin is thus separated, the blood no longer coagulates when allowed to remain at rest, but a spongy flaky matter separates from it, and swims on the surface†.

When blood is dried by a gentle heat, water exhales from it, retaining a very small quantity of animal matter in solution, and consequently having the odour of blood. Blood dried in this manner being introduced into a retort and distilled, there comes over, first a clear watery liquor, then carbonic acid gas, and carbonate of ammonia, which crystallizes in the neck of the retort; after these products there comes over a fluid oil, carbonated hydrogen gas, and an oily substance of the consistence of butter. The watery liquor possesses the property of precipitating from sulphate of iron a green powder: muriatic acid dissolves part of this powder, and there remains behind a little prussian blue. Consequently this watery liquor contains both an alkali and prussic acid‡.

Action of  
heat on  
blood.

9216 grains of dried blood being put into a large

\* Fourcroy, ix. 152.

† Fourcroy, *Ann. de Chim.* vii. 146.

‡ Ibid. 153.

Book V.

crucible, and gradually heated, at first became nearly fluid, and swelled up considerably, emitted a great many fetid fumes of a yellowish colour, and at last took fire and burned with a white flame, evidently owing to the presence of oil. After the flame and the fumes had disappeared, a light smoke was emitted, which affected the eyes and the nose; it had the odour of prussic acid, and reddened moist paper stained with vegetable blue. At the end of six hours, when the matter had lost five-sixths of its substance, it melted anew, exhibited a purple flame on its surface, and emitted a thick smoke. This smoke affected the eyes and nostrils, and reddened blue paper, but it had not the smell of prussic acid. When a quantity of it was collected and examined, it was found to possess the properties of phosphoric acid. The residuum amounted to 181 grains; it had a deep black colour and a metallic brilliancy; and its particles were attracted by the magnet. It contained no uncombined soda, though the blood itself, before combustion, contains it abundantly; but water extracted from it muriate of soda: part of the remainder was dissolved by muriatic acid, and of course was lime; there was besides a little silica, which had evidently been separated from the crucible. The iron had been reduced during the combustion\*.

Component  
parts of  
blood.

Such are the properties of blood, as far as they have been hitherto ascertained by experiment. We have seen that it contains the following ingredients:

- |           |             |
|-----------|-------------|
| 1. Water  | 3. Albumen  |
| 2. Fibrin | 4. Gelatine |

\* Fourcroy, *Ann. de Chim.* vii. 151.

hydrosulph. of ammonia    8. Muriate of soda  
 la                                9. Phosphate of soda  
 b-phosphate of iron    10. Phosphate of lime  
 es benzoic acid, which has been detected by Proust.  
 But our knowledge of this singular fluid is by no  
 so complete as it ought to be; a more accurate  
 sis would probably discover the presence of other  
 nces, and enable us to account for many of the  
 ries of blood which at present are inexplicable.  
 would be of great consequence also to compare  
 the blood of different animals, and of the same  
 l at different ages, and to ascertain in what parti-  
 they differ from each other. This would pro-  
 throw light on some of the obscurest parts of the  
 l economy. Very little progress has hitherto been  
 in these researches. If we except the labours of  
 lle, who obtained nearly the same ingredients,  
 h in different proportions, from the blood of a  
 variety of animals, the experiments of Fourcroy  
 e blood of the human fœtus are almost the only  
 of that kind with which we are acquainted.

found that it differs from the blood of the adult  
 ee things: 1. Its colouring matter is darker, and  
 to be more abundant; 2. It contains no fibrin,  
 robably a greater proportion of gelatine than blood  
 ults; 3. It contains no phosphoric acid\*.  
 e examination of diseased blood, too, would be of  
 consequence; because the difference of its proper-  
 rom the blood of people in health might throw  
 light on the nature of the disease.

Blood of  
 the fœtus.

\* Fourcroy, *Ann. de Chim.* vii. 162.



---

SECT. XI.

## OF MILK.

**MILK** is a fluid secreted by the female of all those animals denominated *mammalia*, and intended evidently for the nourishment of her offspring.

The milk of every animal has certain peculiarities which distinguish it from every other milk. But the animal whose milk is most made use of by man as an article of food, and with which, consequently, we are best acquainted, is the *cow*. Chemists, therefore, have made choice of cow's milk for their experiments. I shall at first confine myself to the properties and analysis of cow's milk, and afterwards point out in what respect the milk of other animals differs from it, as far at least as these differences have hitherto been ascertained.

Milk is an opaque fluid, of a white colour, a slight peculiar smell, and a pleasant sweetish taste. When newly drawn from the cow, it has a taste very different from that which it acquires after it has been kept for some hours. It reddens vegetable blues.

Properties  
of milk.

Its boiling and freezing points are nearly the same as those of water; but they vary a few degrees in different milks\*. Milk is specifically heavier than wa-

---

\* *Jour. de Phys.* xxviii. 362.



Book V.

Spontaneous decomposition.

ter, and lighter than blood ; but the precise degree cannot be ascertained, because almost every particular milk has a specific gravity peculiar to itself.

When milk is allowed to remain for some time at rest, there collects on its surface a thick unctuous yellowish coloured substance, known by the name of *cream*.

After the cream is separated, the milk which remains is much thinner than before, and it has a bluish white colour. If it be heated to the temperature of  $100^{\circ}$ , and a little *rennet*, which is water digested with the inner coat of a calf's stomach and preserved with salt, be poured into it, coagulation ensues ; and if the coagulum be broken, the milk very soon separates into two substances ; a solid white part, known by the name of *curd*, and a fluid part called *whey*. Thus we see that milk may be easily separated into three parts ; namely, *cream*, *curd*, and *whey*.

1. *CREAM* is of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In three or four days it becomes so thick that the vessel which contains it may be inverted without risking any loss. In eight or ten days more, its surface is covered over with mucors and byssi, and it has no longer the flavour of cream, but of very fat cheese \*. This is the process for making what in this country is called a *crisen cheese*.

Cream

Cream possesses many of the properties of an oil. It is specifically lighter than water ; it has an unctuous feel, stains clothes precisely in the manner of oil ; and if it be kept fluid, it contracts at last a taste which is

---

\* Parmentier and Deycns, *Jour. de Phys.* 221viii. 374.

very analogous to the rancidity of oils \*. When kept boiling for some time, a little oil makes its appearance, and floats upon its surface †. Cream is neither soluble in alcohol nor oils ‡. These properties are sufficient to show us that it contains a quantity of oil; but this oil is combined with a part of the curd, and mixed with some serum. Cream, then, is composed of a peculiar oil, curd, and serum. The oil may be easily obtained separate by agitating the cream for a considerable time. This process, known to every body, is called *churning*. After a certain time, the cream separates into two portions: one fluid, and resembling creamed milk; the other solid, and called *butter*.

Converted  
into butter.

Butter is of a yellow colour, possesses the properties of an oil, and mixes readily with other oily bodies. When heated to the temperature of  $96^{\circ}$  it melts, and becomes transparent; if it be kept for some time melted, some curd and water or whey separate from it, and it assumes exactly the appearance of oil §. But this process deprives it in a great measure of its peculiar flavour.

When butter is kept for a certain time, it becomes rancid, owing in a good measure to the presence of these foreign ingredients; for if butter be well washed, and a great portion of these matters separated, it does not become rancid nearly so soon as when it is not treated in this manner. It was formerly supposed that this rancidity was owing to the developement of a peculiar acid; but Parmentier and Deyeux have shown that no

\* Parmentier and Deyeux, *Jour. de Phys.* xxxviii. 375.

† Ibid. 374.

‡ Ibid.

§ Fourcroy, *Ann. de Chim.* vii. 170.

mena, it can scarcely be doubted that this gas is carbonic acid. Dr Young affirms, that during the churning there is an increase of temperature amounting to four degrees.

The affinity of the oil of cream for the other ingredients is such, that it never separates completely from them. Not only is curd and whey always found in the cream, but some of this oil is constantly found in creamed milk and even in whey: for it has been ascertained by actual experiment, that butter may be obtained by churning whey. 27 Scotch pints of whey yield at an average about a pound of butter\*. This accounts for a fact well known to those who superintend dairies, that a good deal more butter may be obtained from the same quantity of milk, provided it be churned as drawn from the cow, than when the cream alone is collected and churned.

The butter-milk, as Parmentier and Deyeux ascertained by experiment, possesses precisely the properties of milk deprived of cream†.

2. CURD, which may be separated from creamed milk by rennet, has many of the properties of coagulated albumen. It is white and solid; and when all the moisture is squeezed out, it has a good deal of brittleness. It is insoluble in water; but pure alkalies and lime dissolve it readily, especially when assisted by heat; and when fixed alkali is used, a great quantity of ammonia is emitted during the solution. The solution of curd in soda is of a red colour, at least if heat be employed; owing probably to the separation of charcoal

Properties  
of curd.

\* *Mid-Lotbian Reports* for 1795.

† *Jour. de Phys.* xlviii. 379.



Curd, as is well known, is used in making *cheese*; and the cheese is the better the more it contains of cream, or of that oily matter which constitutes cream. It is well known to cheesemakers, that the goodness of it depends in a great measure on the manner of separating the whey from the curd. If the milk be much heated, the coagulum broken in pieces, and the whey forcibly separated, as is the practice in many parts of Scotland, the cheese is scarce good for any thing; but the whey is delicious, especially the last squeezed out whey, and butter may be obtained from it in considerable quantity:—a full proof that nearly the whole creamy part of the milk has been separated with the whey. Whereas if the milk be not too much heated (about  $100^{\circ}$  is sufficient), if the coagulum be allowed to remain unbroken, and the whey be separated by very slow and gentle pressure, the cheese is excellent; but the whey is almost transparent, and nearly colourless.

Chap. II.  
Of cheese.

Good cheese melts at a moderate heat; but bad cheese, when heated, dries, curls, and exhibits all the phenomena of burning horn. From this it is evident, that good cheese contains a quantity of the peculiar oil which constitutes the distinguishing characteristic of cream; hence its flavour and smell. Proust has found in cheese an acid which he calls the *caseic* acid, to which he ascribes several of the peculiar properties of cheese †.

This resemblance of curd and albumen makes it probable that the coagulation of milk and of albumen depend upon the same cause. Heat, indeed, does not coa-

Coagulation of milk.

\* Parmentier and Deyeux, *Jour. de Phys.* xxviii. 417.—Fourcroy, *Ibid.* p. 173.

† *Jour. de Phys.* lxi. 107.



whey for some time boiling; a thick white scum gathers on the surface, which in Scotland is known by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being allowed to remain at rest for some hours, to give the remainder of the curd time to precipitate, is decanted off almost as colourless as water, and scarcely any of the peculiar taste of milk can be distinguished in it. If it be now slowly evaporated, it deposits at last a number of white-coloured crystals, which are *sugar of milk*. Toward the end of the evaporation, some crystals of muriate of potash and of muriate of soda make their appearance\*. According to Scheele, it contains also a little phosphate of lime†, which may be precipitated by ammonia.

Contains  
sugar of  
milk,

Salts.

The recent experiments of Fourcroy and Vauquelin, Thenard, and Bouillon La Grange, have added considerably to our knowledge of the constituents of whey. It always reddens vegetable blues, containing a portion of acetic acid. The lactic acid of Scheele is nothing else than this acid holding an animal matter in solution‡. It contains likewise some phosphate of magnesia and phosphate of iron, as Fourcroy and Vauquelin have discovered§. Sulphate of potash, likewise, and a peculiar extractive matter, have been separated from it.

Milk is one of the few animal substances which may be made to undergo the vinous fermentation, and to af-

Milk ca-  
pable of the  
vinous fer-  
mentation.

\* Parmentier, *Jour. de Phys.* xxxviii. 437.

† Scheele, ii. 61.

‡ Bouillon la Grange, *Ann. de Chim.* l. 272.—Vauquelin, Gehlen's *Jour.* iii. 456.

§ Gehlen, *Ibid.*

gave the name of *franchipann*. This substance, when the fire is increased, yields at first a transparent liquid, which becomes gradually more coloured; some very fluid oil comes over, then ammonia, an acid, and at last a very thick black oil. Towards the end of the process carbureted hydrogen gas is disengaged\*. There remains in the retort a coal, which contains carbonate of potash, muriate of potash, and phosphate of lime, and sometimes magnesia, iron, and muriate of soda†.

Thus we see that cow's milk is composed of the following ingredients:

- |                  |                           |
|------------------|---------------------------|
| 1. Water         | 7. Muriate of soda        |
| 2. Oil           | 8. Muriate of potash      |
| 3. Curd          | 9. Sulphate of potash     |
| 4. Extractive    | 10. Phosphate of lime     |
| 5. Sugar of milk | 11. Phosphate of magnesia |
| 6. Acetic acid   | 12. Phosphate of iron     |

Its composition.

The milk of all other animals, as far as it has hitherto been examined, consists nearly of the same ingredients: but there is a very great difference in their proportion.

WOMAN'S MILK has a much sweeter taste than cow's milk. When allowed to remain at rest for a sufficient time, a cream gathers on its surface. This cream is more abundant than in cow's milk, and its colour is usually much whiter. After it is separated, the milk is exceedingly thin, and has the appearance rather of

Woman's milk.

\* Parmentier, *Jour. de Phys.* xxvii. 368.

† *Mém. Med. Par.* 1787, p. 607.

1. It contains a much smaller quantity of curd.
2. Its oil is so intimately combined with its curd that it does not yield butter.
3. It contains rather more sugar of milk.

Parmentier and Deyeux ascertained that the quantity of curd in woman's milk increases in proportion to the time after delivery \*. Nearly the same thing has been observed with respect to cow's milk.

Ass's MILK has a very strong resemblance to human milk : It has nearly the same colour, smell, and consistence. When left at rest for a sufficient time, a cream forms upon its surface, but by no means in such abundance as in woman's milk. This cream, by very long agitation, yields a butter, which is always soft, white, and tasteless ; and, what is singular, very readily mixes again with the butter-milk ; but it may be again separated by agitation, while the vessel, which contains it, is plunged in cold water. Creamed ass's milk is thin, and has an agreeable sweetish taste. Alcohol and acids separate from it a little curd, which has but a small degree of consistence. The serum yields sugar of milk and muriate of lime †.

Ass's milk.

Ass's milk therefore differs from cow's milk in three particulars :

1. Its cream is less abundant and more insipid.
2. It contains less curd.
3. It contains more sugar of milk : the proportion is 35 : 80.

GOAT'S MILK, if we except its consistence, which is greater, does not differ much from cow's milk. Like

Goat's milk.

\* Parmentier, *Jour. de Phys.* xxviii. 422.  
Vol. V.

† Ibid. 423.



**Pork V.** that milk, it throws up abundance of cream, from which butter is easily obtained. The creamed milk coagulates just as cow's milk, and yields a greater quantity of curd. Its whey contains sugar of milk, muriate of lime, and muriate of soda \*.

**Ewe's milk.** **EWE'S MILK** resembles almost precisely that of the cow. Its cream is rather more abundant, and yields a butter which never acquires the consistence of butter from cow's milk. Its curd has a fat and viscid appearance, and is not without difficulty made to assume the consistence of the curd of cow's milk. It makes excellent cheese †.

**Mare's milk.** **MARE'S MILK** is thinner than that of the cow, but scarcely so thin as human milk. Its cream cannot be converted into butter by agitation. The creamed milk coagulates precisely as cow's milk, but the curd is not so abundant. The serum contains sugar of milk, sulphate of lime, and muriate of lime ‡.

---

## SECT. XII.

### OF EGGS.

**Contents of eggs.** **THE** eggs of fowls contain two distinct liquids; namely, the *white* and the *yolk*.

---

\* Parmentier, *Jour. de Phys.* xxxviii. 415.

† Ibid. 428.

‡ Ibid. 431.



The white is a glary insipid liquid, often used as of varnish, and to clarify turbid liquors. For most accurate experiments on the composition of liquid we are indebted to Dr Bostock. It had been considered as almost pure albumen, but he has shown it is of a more compound nature. When heated it coagulates; but a small portion remains liquid, which, when evaporated to dryness, leaves a residue possessing the properties of mucus. From the experiments of Bostock, it follows that white of egg is composed of

The white.

Water .....	80.0
Albumen .....	15.5
Mucus .....	4.5

---

 100.0 \*

It contains some traces of soda, of sulphureted hydrogen and of benzoic acid.

The yolk has a mild oily taste; when boiled, it becomes solid, and easily separates into small particles. If now heated for some time in a pan, it softens; when squeezed between the fingers, drops of oil are forced out. If put into linen in this state and pressed, an oil may be forced out. This oil is of a yellow colour and insipid, unless too much heat has been employed in preparing it. Its properties are those of *fixed* oil, or rather of semifluid fat. Chandelier obtained this oil without the assistance of heat †.

The yolk

Contains oil,

The residue, after the separation of the oil, possesses the properties of albumen, though it is still a little co-

Albumen,

---

\* Nicholson's Jour. xi. 246; and xiv. 242.

† Jour. de Med. xvi. 43.

Book V.

loured by the remains of the oil. Hence, when washed with water, a kind of emulsion is obtained. It is owing to the presence of albumen that the yolk hardens when heated.

And gelatine.

When this albumen is boiled in water, the liquid is said to separate a little gelatine. Thus it appears that the yolk consists of four constituents :

1. Water
2. Oil
3. Albumen
4. Gelatine.

The knowledge of its component parts enables us, without difficulty, to explain the changes produced upon the yolk by the action of different reagents.

Action of potash.

Mr Hatchett found that when yolk is boiled with potash, it forms a pale olive-coloured concrete animal soap, which, when dissolved in water, and saturated with muriatic acid, is thrown down in the state of fat. When burnt the yolk leaves a small residuum of phosphate of lime and phosphate of soda \*.

When agitated with water, the yolk forms a white emulsion like milk. The principal use of the yolk is to serve for food to the chicken before it bursts the shell.

3. The membranes in which these two liquids are inclosed, consist most probably of coagulated albumen.

---

\* Hatchett, *Phil. Trans.* 1800.

## SECT. XIII.

## OF SALIVA.

THE fluid secreted in the mouth, which flows in considerable quantity during a repast, is known by the name of *saliva*. All the properties of this liquor which had been observed by philosophers before the middle of the 16th century have been collected by Haller\* : But since that time several additional facts have been related by Fourcroy, Du Tennifer, and Brugnatelli ; and a very numerous set of experiments have been published by Mr Siebold in 1797, in his *Treatise on the Salivary System*. History.

Saliva is a limpid fluid like water ; but much more viscid : it has neither smell nor taste. Its specific gravity, according to Hamberger, is 1.0167† ; according to Siebold, 1.080. When agitated, it froths like all other adhesive liquids ; indeed it is usually mixed with air, and has the appearance of froth. Properties.

It neither mixes readily with water nor oil ‡ ; but by trituration in a mortar it may be so mixed with water as to pass through a filter §. It has a great affinity for oxygen, absorbs it readily from the air, and gives it

\* Haller's *Physiology*, vol. vi.  
id. p. 34.

† Ibid. p. 52.

‡ Lardier on *Digest*. p. 51.

When saliva is distilled in a retort, it froths very much : 100 parts yield 80 parts of water nearly pure, then a little carbonate of ammonia, some oil, and an acid, which perhaps is the prussic. The residuum amounts to about 1.56 part, and is composed of muriate of soda, phosphate of soda, and phosphate of lime \*.

The acids and alcohol inspissate saliva ; the alkalies disengage ammonia ; oxalic acid precipitates lime ; and the nitrates of lead, mercury, and silver, precipitate phosphoric and muriatic acids.

From these facts, it follows that saliva, besides water, which constitutes at least four-fifths of its bulk, contains the following ingredients :

- |                    |                          |
|--------------------|--------------------------|
| 1. Mucilage        | 4. Phosphate of soda     |
| 2. Albumen         | 5. Phosphate of lime     |
| 3. Muriate of soda | 6. Phosphate of ammonia. |

But it cannot be doubted that, like all the other animal fluids, it is liable to many changes from disease, &c. Brugnatelli found the saliva of a patient labouring under an obstinate venereal disease impregnated with oxalic acid †.

The concretions which sometimes form in the salivary ducts, &c. and the tartar or bony crust which so often attaches itself to the teeth, are composed of phosphate of lime ‡.

Such are the properties of human saliva. The saliva of the horse was analysed by Hapel Delachenier in 1780. He collected 12 ounces of it in the space of 24 hours by puncturing the salivary duct. Its colour was

Saliva of  
the horse.

\* Vorbeyen, Textor, Nuck, &c. as quoted by Haller, *Physiol.* vi. 55. Fourcroy, ix. 365.

† *Jour. de Phys.* lxxiii. 215.

‡ Fourcroy, ix. 367.



quantities of it are usually found collected in the gall bladder. Chap. II.

Great attention has been paid to this liquid by physicians; because the ancients were accustomed to ascribe a very great number of diseases, and even affections of the mind, to its agency. Several important observations were made on it by Boyle, Boerhaave, Verheyen, Ramsay, and Baglivi; and some facts have since been added to our chemical knowledge of bile by Macbarg and Fourcroy. But the most accurate chemical analyses were those of Cadet, published in the *Memoirs of the French Academy* for 1767, and of Van Boehante, published in 1778, till Thenard read his very ingenious experiments on it to the National Institute in 1805\*. To him we are indebted not only for the first accurate analysis of ox bile, which, being most easily procured in quantities, has usually been chosen as the subject of chemical researches; but likewise for an examination of human bile, and that of several of the inferior animals, and for a comparison of these liquids with ox bile. History.

I shall in the first place state the nature and properties of ox bile, and then give an account of the bile of other animals as far as it has been examined.

1. Ox bile is a liquid of a yellowish green and sometimes of a deep green colour. Its taste is very bitter, but at the same time sweetish. Its smell is feeble, but peculiar and disagreeable. It does not act on vegetable blues. Its consistence varies very much. Sometimes it is a thin mucilage; sometimes very viscid and glutinous. Properties  
of ox bile.

---

\* *Mém. d'Arcueil*, i. 23. and 46.

Book V.

nous; sometimes it is perfectly transparent, and sometimes it contains a yellow coloured matter which precipitates when the bile is diluted with water.

The specific gravity of ox bile seems to vary, like that of all other animal fluids. According to Hartmann, it is 1.027\*; according to Thenard, 1.026 at the temperature of 43°. When strongly agitated, it lathers like soap; and for this reason, as well as from a medical theory concerning its use, it has been often called an *animal soap*.

Action of heat.

It mixes readily with water in any proportion, and assumes a yellow colour; but it refuses to unite with oil; when the two fluids are agitated together, the instant that they are left at rest the oil separates and swims on the surface†. Bile, however, dissolves a portion of soap readily, and is often employed to free cloth from greasy spots.

When distilled to dryness it becomes at first slightly muddy; then it froths violently, and a colourless liquid passes into the receiver, having a smell similar to that of bile, and slightly precipitating superacetate of lead. The residue in the retort, when well dried, amounts to from  $\frac{1}{4}$ th to  $\frac{1}{2}$ th of the whole. It has a greenish yellow colour, a very bitter taste, slightly deliquesces in the air, and is almost totally soluble in water and alcohol. When strongly heated it is decomposed, and gives the usual products of animal substances; only the proportion of oil is greater, and that of carbonate of ammonia smaller, than what is furnished by most ani-

---

\* Haller's *Phys.* vi. 346.

† Ramazzini, *Thesaur. Med. Edin.* ii. 459.—Macbarg, p. 10.

mal bodies. A voluminous charcoal remains behind containing soda and several saline bodies; namely, common salt, phosphate of soda, sulphate of soda, phosphate of lime, and some traces of oxide of iron. The soda does not exceed  $\frac{1}{100}$ th part of the bile.

When an acid is added to bile, even in a minute quantity, it acquires the property of reddening vegetable blues. The addition of a little more acid occasions a precipitate, and sulphuric acid occasions a greater precipitate than any other acid. This precipitate consists of a yellow coloured matter often visible in bile, and which is insoluble in water. It contains also a little resin which gives it a bitter taste. Acids do not throw down the whole resin from bile. Yet if the resin be dissolved in soda, it is readily precipitated by all the acids; a proof that the resin is not kept in solution in bile by soda.

When superacetate of lead is poured into bile a copious white precipitate falls, consisting of the resin combined with the oxide of lead. The superacetate of commerce does not readily throw down the whole resin; but if eight parts of common sugar of lead and one part of litharge be united together by digestion in water, a salt is formed which readily throws down the whole of the resin. If the precipitate be treated with diluted nitric acid the lead is separated, and the resin remains behind in a state of purity. It is a green coloured, bitter tasted substance, possessing most of the properties of resins. It has been already described in the preceding Chapter. One hundred parts of bile contain about three parts of resin.

If acetate of lead be poured into bile thus deprived of its resin by the superacetate, a new and more copious

Resin.

Picromel.

## Book V.

precipitate falls, consisting of the oxide of lead united to a peculiar substance, which gives bile most of its characters. This substance was first described in detail by Thenard, who has given it the name of *picromel*. The compound consisting of oxide of lead and picromel is soluble in acetic acid. If a current of sulphureted hydrogen gas be passed through the solution, the lead is separated; and by filtering and evaporating the liquid to dryness, the picromel is obtained in a separate state. When bile, mixed with muriatic acid and filtered, is set aside for some months in an open vessel, I have seen the picromel separate of its own accord. It is a white solid substance in small globules. It has a sweet, and at the same time an acrid taste, and is often somewhat bitter from retaining a portion of the resin. It facilitates the solution of resin in water; three parts of picromel and one part of resin dissolve in water. The addition of soda facilitates the solution of the resin. Ox bile consists essentially of picromel, resin, and soda, united together, and dissolved in water. The picromel prevents the precipitation of the resin by acids, and it prevents the soda from leaving the resin and uniting with acids.

Constitu-  
ents.

By evaporating a quantity of bile to dryness, calcining it, and proceeding in the usual way, Thenard ascertained the proportion of salts which it contained. The following was the result of his analysis of 800 parts of bile.



700.0	water
24.0	resin
60.3	picromel
4.5	yellow matter
4.0	soda
2.0	phosphate of soda
3.2	muriate of soda
0.8	sulphate of soda
1.2	phosphate of lime
	oxide of iron, a trace

---

 800.0

The albumen, announced as a constituent of ox bile by Cadet \* and Ramsay †, was not found by Thenard. There is no doubt, however, that various species of bile contains albumen. I have found it myself in human bile, and there is every reason to believe that it at least occasionally exists in ox bile.

Ox bile owes its colour, taste, and smell, in a great measure to its resinous constituent. This resin is a solid substance of a bitter taste and a green colour. When melted it becomes yellow. It is very soluble in alcohol and in alkalies. Water dissolves some traces of it at a boiling heat. When sulphuric acid is poured into this water the resin is precipitated, but none of the other acids have that effect.

The picromel is a white solid substance very soluble in water and alcohol, and precipitated by nitrate of mercury, the salts of iron, and the acetate of lead. With soda and resin it forms a triple compound not decomposed by acids, nor alkaline and earthy salts.

---

\* *Mém. Par.* 1767, p. 340.

† *Thésaur. Edin.* ii. 460.

## Book V.

The yellow matter is the substance to which bile owes its tendency to putrefaction. It is insoluble in water, but is dissolved by the fixed alkaline solutions, and is precipitated by acids.

## Bile of other animals.

2. Such are the properties and the constituents of ox bile, as far as they have been examined by Thenard. From the experiments of the same chemist it appears, that the bile of the calf, the dog, the sheep, and the cat, resemble that of the ox exactly, both in their properties and their constituents \*.

## Of the sow.

3. The bile of the sow differs entirely from that of all these animals. It contains neither albumen, nor animal matter, nor picromel, but is merely a soap, as it contains a great quantity of resin and of soda, and is decomposed with facility by all the acids, even by vinegar. It contains traces also of several salts; but Thenard did not ascertain their nature †.

## Of fowls.

4. The bile of the common hen, of the turkey, and the duck, has a good deal of resemblance to that of quadrupeds. But it differs in the following particulars: 1. It contains a considerable quantity of albumen; 2. The picromel has no sensible sweet taste, but is very acrid and bitter; 3. It contains very little soda; 4. The resin is not precipitated by common superacetate of lead; but superacetate, boiled with  $\frac{1}{2}$ th of its weight of litharge, occasions it to precipitate ‡.

## Of fishes.

5. The bile of the thornback and salmon is yellowish white. When evaporated it leaves a matter which has a very sweet and slightly acrid taste. It appears to contain no resin. The bile of the carp and the eel is

\* *Mém. d'Arcueil*, i. 48.† *Ibid.* p. 49.‡ *Ibid.* p. 50.

very green, very bitter, contains little or no albumen, but yields soda, resin, and a sweet acrid matter similar to that which may be obtained from salmon bile \*.

Chap. II.

6. Human bile differs considerably from that of all other animals examined. Its colour is sometimes green, sometimes yellowish brown; sometimes it is nearly colourless. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness it leaves a brown matter amounting to about  $\frac{1}{11}$ th of the original weight. When this matter is calcined it yields all the salts which are to be found in ox bile. All the acids decompose human bile, and throw down a copious precipitate consisting of albumen and resin. One part of nitric acid is capable of saturating 100 parts of bile. The superacetate of lead throws down the resin, and leaves nothing but a yellowish liquid consisting of the salts of bile, and some atoms of a peculiar animal matter, the nature of which was not ascertained. Thus it appears that human bile contains no picromel. The following were the proportions of these substances obtained by Thenard from 1100 parts of human bile :

Human  
bile.

1000·0 water

from 2 to 10 yellow insoluble matter

yellow matter in solution, a trace

42·0 albumen

41·0 resin

5·6 soda

4·5 phosphate of soda, sulphate of soda, muriate of soda, phosphate of lime, oxide of iron

Constitu-  
ents.

\* *Mem. d'Arsueil*, i. 53.

Book V.

The yellow matter is insoluble in water, alcohol, and oils, but soluble in alkalies, and precipitated in greenish brown flocks by acids. Muriatic acid scarcely dissolves it, but gives it a brownish green colour, and then it is exactly similar to the yellow matter of ox bile.

The resin is yellowish, very fusible and very bitter. It dissolves readily in alcohol, and is precipitated by the acids. It is nearly insoluble in water, though not altogether so\*.

Such are the properties and constituents of all the different species of bile hitherto subjected to chemical examination.

## SECT. XV.

## OF THE CERUMEN OF THE EAR.

**CERUMEN** is a viscid yellow-coloured liquid secreted by the glands of the auditory canal, which gradually becomes concrete by exposure to the air. For all the facts respecting its composition at present known, we are indebted to Fourcroy and Vauquelin, especially the last, who analysed a considerable portion of it.

Properties.

It has an orange-yellow colour and a bitter taste. When slightly heated upon paper, it melts, and stains

\* Thenard, *Mém. d'Arcueil*, i. 53.



Chap. II.

the paper like an oil ; at the same time it emits a slightly aromatic odour. On burning coals it softens, emits a white smoke, which resembles that given out by burning fat ; it afterwards melts, swells, becomes dark-coloured, and emits an ammoniacal and empyreumatic odour. A light coal remains behind.

When agitated in water, cerumen forms a kind of emulsion, which soon putrefies, depositing at the same time white flakes.

Alcohol, when assisted by heat, dissolves  $\frac{1}{2}$  of the cerumen ; the  $\frac{1}{2}$  which remain behind have the properties of albumen, mixed however with a little oily matter. When the alcohol is evaporated, it leaves a deep orange residuum of a very bitter taste, having a smell and a consistence analogous to turpentine. It melts when heated, evaporates in a white smoke without leaving any residuum, and in short resembles very strongly the *resin of bile*. Ether also dissolves this oily body ; but it is much less bitter and much lighter coloured. When the albuminous part of cerumen is burnt, it leaves traces of soda and of phosphate of lime. From these facts Vauquelin considers cerumen as composed of the following substances :

Contains  
albumen

And resin.

- |                       |                       |
|-----------------------|-----------------------|
| 1. Albumen            | 4. Soda               |
| 2. An inspissated oil | 5. Phosphate of lime. |
| 3. A colouring matter |                       |

Composi-  
tion.

The presence of the colouring matter is inferred from the portion taken up by ether being less coloured than that taken up by alcohol \*.

\* Fourcroy, ix. 373.

## SECT. XVI.

## OF TEARS AND MUCUS.

1. **THAT** peculiar fluid which is employed in lubricating the eye, and which is emitted in considerable quantities when we express grief by weeping, is known by the name of *tears*. For an accurate analysis of this fluid we are indebted to Messrs Fourcroy and Vauquelin. Before their dissertation, which was published in 1791, appeared, scarcely any thing was known about the nature of tears.

*Properties.*

The liquid called tears is transparent and colourless like water; it has scarcely any smell, but its taste is always perceptibly salt. Its specific gravity is somewhat greater than that of distilled water. It gives to paper stained with the juice of the petals of mallows or violet a permanently green colour, and therefore contains a fixed alkali\*. It unites with water, whether cold or hot, in all proportions. Alkalies unite with it readily, and render it more fluid. The mineral acids produce no apparent change upon it†. Exposed to the air, this liquid gradually evaporates, and becomes thicker. When nearly reduced to a state of dryness, a number of cubic crystals form in the midst of a kind of mullage. These crystals possess the properties of marine

\* Fourcroy and Vauquelin, *Jour. de Phys.* xxxix. 256.    † *Ibid.* 257.

is ; but they tinge vegetable bluesgreen, and therefore contain an excess of soda. The mucilaginous matter requires a yellowish colour as it dries.\*

This liquid boils like water, excepting that a considerable froth collects on its surface. If it be kept a long time at the boiling temperature,  $\frac{2}{100}$  parts evaporate in water, and there remain about .04 parts of yellowish matter, which by distillation in a strong retort yields water and a little oil: the residuum consists of ferent saline matters †.

When alcohol is poured into this liquid, a mucilaginous matter is precipitated in the form of large white flocks. The alcohol leaves behind it, when evaporated, a residue of muriate of soda and soda. The residuum which remains behind, when inspissated tears are burnt in the air, exhibits some traces of phosphate of lime and phosphate of soda ‡.

Thus it appears that tears are composed of the following ingredients :

1. Water	4. Soda	Composition.
2. Mucus	5. Phosphate of lime	
3. Muriate of soda	6. Phosphate of soda.	

The saline parts amount only to about 0.01 of the tears, or probably not so much.

The mucus contained in the tears has the property of absorbing oxygen gradually from the atmosphere, and becoming thick and viscid, and of a yellow colour. It is then insoluble in water, and remains long suspended in it without alteration. When a sufficient quantity of oxymuriatic acid is poured into tears, a yel-

Properties  
of the mu-  
cilage.

Fourcroy and Vauquelin, *Jour. de Phys.* XXIX. 256.  
Ibid. 259.

† Ibid.



Book V.

low flaky precipitate appears, absolutely similar to that inspissated mucus. The oxymuriatic acid loses its peculiar odour; hence it is evident that it has given out oxygen to the mucus. The property which this mucus has of absorbing oxygen, and of acquiring new qualities, explains the changes which take place in tears which are exposed for a long time to the action of the atmosphere, as is the case in those persons who labour under a fistula lachrymalis \*.

Mucus of the nose.

2. The MUCUS of the nose has also been examined by Fourcroy and Vauquelin. They found it composed of precisely the same ingredients with the tears. As this fluid is more exposed to the action of the air than the tears, in most cases its mucus has undergone less or more of that change which is the consequence of the absorption of oxygen. Hence the reason of the greater viscosity and consistence of the mucus of the nose; hence also the great consistence which it acquires during colds, where the action of the atmosphere is assisted by the increased action of the parts †.

Of cavities.

3. As to the MUCUS which lubricates the alimentary canal, the trachea, the bronchiæ, the urethra, and all the different cavities of the body, nobody has hitherto subjected it to analysis, because it cannot be obtained in sufficient quantity. It is viscid, and no doubt contains a mucilaginous substance, similar to that contained in the saliva, the tears, and the mucus of the nose; as, like these liquids, it is liable to become much thicker by exposure to the air.

---

\* Fourcroy and Vauquelin, *Jour. de Phys.* t. xix. p. 257.

† Ibid. p. 259.



the matter expectorated from the lungs and bronchiae is to be supposed to be mucilaginous; but from the experiments on it by Dr Pearson, who has examined it with much care and ingenuity\*, this does not appear to be the case. Dr Pearson distinguishes seven different kinds of expectorated matter. 1. The jelly-like transparent kind of a bluish hue, excreted in a state of health; 2. The thin mucilage-like transparent matter copiously expectorated in bronchial catarrhs; 3. The opaque straw-coloured, or white and very tenacious matter, coughed up in a great variety of bronchial and pulmonary affections, especially in that of tubercles; 4. The uniform matter, secreted without any division of consistency or breach of surface of the bronchial membrane, very commonly occurring in pulmonary congestions; 5. The matter which consists of opaque solid masses, together with transparent fluid; or the solid sort above stated with nodules of the third and fourth kind; 6. Pus from the vomicae of tubercles; 7. Pus from vomicae by simple inflammation of the lungs, and without tubercles. From the experiments of Dr Pearson, it appears that the constituents of the first five of these species are nearly the same. The chief variation is in the proportion of the ingredients. They all consist of water holding in solution a quantity of albumen or animal oxide (Dr Pearson terms it), coagulable by heat and by the chemical agents. This albumen is combined with phosphoric acid which it neutralizes. This albumen sometimes

Expectorated matter.

Composition.

\* Pearson on *Expectorated matter*. *Phil. Trans.* 1809.

† Pearson thinks that the alkali in animal fluids is not soda, as has

## Book V.

amounts to the twelfth or even the tenth of the expectorated matter; and when smallest it is never less than  $\frac{1}{12}$ th. The usual proportion varies from  $\frac{1}{8}$ th to  $\frac{1}{10}$ th. The potash varies between  $\frac{1}{4}$  and  $\frac{1}{2}$ ths of a part in 1000 of the expectorated matter.

Expectorated matter yields traces of sulphur, and perhaps also of phosphorus, and it contains the following saline substances: 1. Muriate of soda, varying from 1; to 2; in the 1000 of expectorated matter; 2. Phosphate of lime about  $\frac{1}{4}$  a part in the 1000; 3. Ammonia united probably to phosphoric acid; 4. A phosphate probably of magnesia; 5. Carbonate of lime; 6. A sulphate; 7. Vitriifiable matter probably silica; 8. Oxide of iron. The whole of these last six substances scarcely amounts to one part in the 1000 of expectorated matter.

The proportion of saline matter and of albumen present in expectorated matter varies much in different circumstances. The thicker it is in general the smaller is the quantity of saline matter; whereas when very thin it is often impregnated with salts, especially with muriate of soda to a great degree, and tastes distinctly salt and hot.

hitherto been supposed, but potash. He has found this to be the case in blood, dropical fluid, pus, liquid from blisters, urine, and mucus of the nose.

## SECT. XVII.

## LIQUOR OF THE PERICARDIUM.

This is a liquor which lubricates the heart. It has lately examined by Dr Bostock, having been obtained from the pericardium of a boy who had died suddenly. It had the colour and appearance of the serum of blood. Evaporated to dryness, it left a residue amounting to  $\frac{1}{17}$ th of its weight. When exposed to the heat of boiling water, it became opaque and thready. It was copiously precipitated by oxymuriate of mercury before boiling; but when boiled, evaporated to dryness, and redissolved, the solution was not affected by muriate of mercury. These experiments show us it contained albumen. When saturated with oxymuriate of mercury, infusion of galls produced no effect, causing the absence of gelatine. It was copiously precipitated by neutral acetate of lead, even after being dried to dryness and the residue redissolved in water. The rate of silver indicated the presence of muriatic acid. Bostock, from his experiments, considers it as composed of



Book V.

Water.....	97.0
Albumen.....	5.5
Mucus .....	2.0
Muriate of soda.....	0.5
	<hr/>
	100.0

## SECT. XVIII.

## OF THE HUMOURS OF THE EYE.

Structure  
of the eye.

THE eye is one of the most delicate and complicated organs in the body ; at the same time its structure, and the uses of its parts, are better understood than almost any of the other instruments of sensation. It is composed of several concentric coats, which have not been chemically examined ; but, from the experiments of Hatchett on similar substances, we may consider it as probable that they possess the properties of coagulated albumen. The internal part of the eye is chiefly filled with three transparent substances, which have been called *humours* by anatomists ; namely, 1. The *aqueous humour*, immediately behind the cornea ; 2. The *crystalline humour* or *lense* ; and, 3. The *vitreous humour*, behind the lense, and occupying the greatest part of the eye. We knew scarcely any thing of the chemical properties of these humours till Mr Chenevix published an analysis of them in the *Philosophical Transactions* for 1802. Since that time an analysis of them has likewise been published by Nicholas\*.

\* *Ann. de Chim.* liii. 307.



1. Most of the experiments of Chenevix were made upon the eyes of sheep, as most easily procured. He afterwards tried the properties of humours from the eyes of other animals.

Chap. II.

Eye of sheep.

1. The aqueous humour of the eye of the sheep is a clear transparent liquid like water, which has very little smell or taste when fresh. Its specific gravity is 1.0090 at the temperature of 60°.

Aqueous humour.

It scarcely alters vegetable blues when fresh. When exposed to the air it evaporates slowly, and becomes slightly putrid. When boiled a very slight coagulum is formed. When 100 parts are evaporated to dryness, they leave eight parts of residuum. Tannin occasions a precipitate in it both before boiling and after it. Nitrate of silver occasions a precipitate of muriate of silver; but no precipitate is produced by other metallic salts. Hence it appears that the aqueous humour is water slightly impregnated with the following substances:

1. Albumen
2. Gelatine
3. Muriate of soda.

For Mr Chenevix found that the muriatic acid was in combination with soda. Nicholas has likewise detected a little phosphate of lime in it.

2. The vitreous matter possesses the very same properties as the aqueous; even its specific gravity is the same, or only a very little greater.

Vitreous humour.

3. The crystalline lense is solid: densest in the centre, and becoming less solid towards the circumference.

Lense.

\* Nicholas found that it turned paper stained with the petals of the mallow to green.

**Book V.** It is composed of concentric coats, and is transparent. Its specific gravity is 1.1000. When fresh it has little taste. It putrefies very rapidly.

It is almost completely soluble in water. The solution is partly coagulated by heat, and gives a copious precipitate with tannin both before the coagulation and after it. It gives no traces of muriatic acid. Hence it is composed of albumen and gelatine united to water. According to Nicholas, the quantity of gelatine diminishes as we approach the centre of the lense, where it is very small. He detected phosphate of lime likewise in every part of the lense.

**Human eye.**

II. The humours of the human eye are composed of the same ingredients as those of the sheep; the only perceptible difference consists in their specific gravity. The specific gravity of the human aqueous and vitreous humours is 1.0053; that of the crystalline 1.0700.

**Eye of oxen.**

III. The humours of the eyes of oxen resemble those of the sheep in their composition. The specific gravity of the aqueous and vitreous humours is 1.0058; that of the crystalline 1.0765.

From these three sets of experiments Mr Cheever has drawn, as a probable conclusion, that the difference between the density of the aqueous and crystalline humours, and that of the crystalline, is in the inverse ratio of the diameter of the eye, taken from the cornea to the optic nerve.

The crystalline of the ox weighed 30 grains. When the whole of it was pared away except the six grains in the centre, the specific gravity was found to be 1.194\*.

\* See *Phil. Trans.* 1807, and *Phil. Mag.* xvi. 262.

IV. Mr Chenevix, in his paper, makes no mention of the eyes of birds; but Mr Davy published an abstract of it in the first volume of the Journal of the Royal Institution. He there states that Mr Chenevix found the humours of the eyes of birds composed of the same constituents as the eyes of other animals; but that he found at the same time the specific gravity of the vitreous humour in these animals greater than the specific gravity of the crystalline \*.

Chap. II.

Eye of  
birds.

## SECT. XIX.

## OF SINOVIA.

WITHIN the capsular ligament of the different joints of the body there is contained a peculiar liquid, intended evidently to lubricate the parts, and to facilitate their motion. This liquid is known among anatomists by the name of *sinovia*.

Whether it be the same in different animals, or even in all the different joints of the same animal, has not been determined, as no accurate analysis of the sinovia of different animals has been attempted. The only analysis of sinovia which has hitherto appeared is that by Mr Margueron, which was published in the 14th volume of the *Annales de Chimie*. He made use of sinovia obtained from the joints of the lower extremities of oxen.

\* Jour. of the Royal Instit. i. 297.



Book V.  
Sinovia of  
the ox.

The sinovia of the ox, when it has just flowed from the joint, is a viscid semitransparent fluid, of a greenish white colour, and a smell not unlike frog-spawn. It very soon acquires the consistence of jelly; and this happens equally whether it be kept in a cold or a hot temperature, whether it be exposed to the air or excluded from it. This consistence does not continue long; the sinovia soon recovers again its fluidity, and at the same time deposits a thready-like matter\*.

Sinovia mixes readily with water, and imparts to that liquid a great deal of viscosity. The mixture froths when agitated; becomes milky when boiled, and deposits some pellicles on the sides of the dish; but its viscosity is not diminished†.

Contains  
albumen.

When alcohol is poured into sinovia, a white substance precipitates, which has all the properties of albumen. One hundred parts of sinovia contain 4.52 of albumen. The liquid still continues as viscid as ever; but if acetic acid be poured into it, the viscosity disappears altogether, the liquid becomes transparent, and deposits a quantity of matter in white threads, which possesses the following properties: 1. It has the colour, smell, taste, and elasticity of vegetable gluten. 2. It is soluble in concentrated acids and pure alkalies. 3. It is soluble in cold water; the solution froths. Acids and alcohol precipitate the fibrous matter in flakes. One hundred parts of sinovia contain 11.86 of this matter‡.

And a fi-  
brous mat-  
ter.

When the liquid, after these substances have been separated from it, is concentrated by evaporation, it

\* Margueron, *Ann. de Chim.* xiv. 124.

† *Ibid.* p. 126.

‡ *Ibid.* p. 126, 130.



deposits crystals of acetate of soda. Sinovia, therefore, contains *soda*. Margueron found that 100 parts of sinovia contained about 0.71 of soda.

When strong sulphuric, muriatic, nitric, acetic, or sulphurous acid is poured into sinovia, a number of white flakes precipitate at first, but they are soon redissolved, and the viscosity of the liquid continues. When these acids are diluted with five times their weight of water, they diminish the transparency of sinovia, but not its viscosity; but when they are so much diluted that their acid taste is just perceptible, they precipitate the peculiar thready matter, and the viscosity of the sinovia disappears\*.

When sinovia is exposed to a dry atmosphere, it gradually evaporates, and a scaly residuum remains, in which cubic crystals, and a white saline efflorescence are apparent. The cubic crystals are muriate of soda. One hundred parts of sinovia contain about 1.75 of this salt. The saline efflorescence is carbonate of soda†.

Sinovia soon putrefies in a moist atmosphere, and during the putrefaction ammonia is exhaled. When it is distilled in a retort, there comes over, first water, which soon putrefies; then water containing ammonia; then empyreumatic oil and carbonate of ammonia. From the residuum muriate and carbonate of soda may be extracted by lixiviation. The coal contains some phosphate of lime‡.

\* Margueron, *Ann. de Chim.* xiv. 127.

† Ibid. p. 128.

‡ Ibid. p. 125.

## SECT. XX.

## OF SEMEN.

THE peculiar liquid secreted in the testes of males, and destined for the impregnation of females, is known by the name of *semen*. The human semen and the melt of fresh water fishes alone have hitherto been subjected to chemical analysis. Nothing is known concerning the seminal fluid of other animals. 1. Vauquelin published an analysis of the human semen in 1791.

Semen, when newly ejected, is evidently a mixture of two different substances: the one fluid and milky, which is supposed to be secreted by the prostate gland; the other, which is considered as the true secretion of the testes, is a thick mucilaginous substance, in which numerous white shining filaments may be discovered \*. It has a slight disagreeable odour, an acrid irritating taste, and its specific gravity is greater than that of water. When rubbed in a mortar it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It converts paper stained with the blossoms of mallows or violets to a green colour, and consequently contains an alkali †.

As the liquid cools, the mucilaginous part becomes transparent, and acquires greater consistency; but in a-

\* Vauquelin, *Ann. de Chim.* ix. 64.† *Ibid.* p. 65.

Book V.

bout twenty minutes after its emission, the whole becomes perfectly liquid. This liquefaction is not owing to the absorption of moisture from the air, for it loses instead of acquiring weight during its exposure to the atmosphere; nor is it owing to the action of the air, for it takes place equally in close vessels \*.

Semen is insoluble in water before this spontaneous liquefaction, but afterwards it dissolves readily in it. When alcohol or oxymuriatic acid is poured into this solution, a number of white flakes are precipitated†. Concentrated alkalis facilitate its combination with water. Acids readily dissolve the semen, and the solution is not decomposed by alkalis; neither indeed is the alkaline solution decomposed by acids‡.

Lime disengages no ammonia from fresh semen; but after that fluid has remained for some time in a moist and warm atmosphere, lime separates a great quantity from it. Consequently ammonia is formed during the exposure of semen to the air§.

Contains  
mucilage,

When oxymuriatic acid is poured into semen, a number of white flakes precipitate, and the acid loses its peculiar odour. These flakes are insoluble in water, and even in acids. If the quantity of acid be sufficient, the semen acquires a yellow colour. Thus it appears that semen contains a mucilaginous substance, analogous to that of the tears, which coagulates by absorbing oxygen. Mr Vauquelin obtained from 100 parts of semen 30 parts of this mucilage.

Phosphate  
of lime,

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a trans-

\* Vauquelin, *Ann. de Chim.* ix. 66.

† Ibid. p. 72.

‡ Ibid. p. 70.

§ Ibid. p. 74.



parent pellicle, and in three or four days deposits small transparent crystals, often crossing each other in such a manner as to represent the spokes of a wheel. These crystals, when viewed through a microscope, appear to be four-sided prisms, terminated by very long four-sided pyramids. They may be separated by diluting the liquid with water, and decanting it off. They have all the properties of phosphate of lime \*. If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface gradually thickens, and a number of white round bodies appear on different parts of it. These bodies also are phosphate of lime, prevented from crystallizing regularly by the too rapid abstraction of moisture. Mr Vauquelin found that 100 parts of semen contain three parts of phosphate of lime †. If at this period of the evaporation the air becomes moist, other crystals appear in the semen, which have the properties of carbonate of soda. The evaporation does not go on to complete exsiccation, unless at the temperature of  $77^{\circ}$ , and when the air is very dry. When all the moisture is evaporated, the semen has lost 0.9 of its weight; the residuum is semitransparent like horn, and brittle ‡.

And soda.

When semen is kept in very moist air, at the temperature of about  $77^{\circ}$ , it acquires a yellow colour, like that of the yolk of an egg; its taste becomes acid, it exhales the odour of putrid fish, and its surface is covered with abundance of the *byssus septica* §.

When dried semen is exposed to heat in a crucible, it melts, acquires a brown colour, and exhales a yellow

Action of heat.

\* Vauquelin, *Ann. de Chim.* ix. p. 67. and 73.

† Ibid. p. 68.

‡ Id. Ibid.

§ Id. Ibid.



some muriate of ammonia, which exists naturally in the milt. When milt is dried slowly in a moderate heat it loses  $\frac{1}{3}$ ths of its weight, becomes yellow and brittle. When heated in a platinum crucible it softens and then melts, exhaling yellow vapours having the smell of animal oil. The charcoal formed contains a notable quantity of uncombined phosphoric acid, together with some phosphate of lime and phosphate of magnesia. As the acid did not exist in the milt it must have been formed during the combustion; and hence it follows that milt contains a notable quantity of phosphorus as a constituent.

Contains  
phosphorus.

123 parts of fresh milt, cautiously distilled in an earthen ware crucible, gradually heated to whiteness, furnished the following products: 1. A great deal of colourless water holding in solution carbonate of ammonia, a good deal of prussiate of ammonia, and traces of muriate of ammonia; 2. A transparent oil slightly yellow; 3. A fluid blood-red oil; 4. A thick blackish brown oil; 5. Crystals of carbonate and prussiate of ammonia; 6. A quantity of phosphorus; 7. A small quantity of carbonic acid and heavy inflammable air. The charcoal remaining in the retort amounts to  $7\frac{1}{2}$  parts, and contains no disengaged phosphoric acid.

When milt is triturated in distilled water a white opaque liquid is obtained, which does not become transparent though passed through the filter. When the liquid is boiled an albuminous matter coagulates; and if the residuary liquid be evaporated sufficiently it gelatinizes; a proof that it contains gelatine. Alcohol digested on milt dissolves a substance which possesses the properties of animal soap. When it is separated the milt becomes dry and harsh to the feel; a proof that

Its specific gravity is 1.005. It gives a green colour to the tincture of violets, and yet it reddens very decidedly the tincture of turnsole. These two properties would indicate at once the presence of an acid and of an alkali. It froths considerably when agitated. On the application of heat it becomes opaque, and has then a great resemblance to milk diluted with a large quantity of water. At the same time it exhales the odour of boiled white of egg\*.

Acids render it more transparent. Alkalies precipitate an animal matter in small flakes. Alcohol likewise produces a flaky precipitate, which, when collected and dried, becomes transparent and very like glue. The infusion of nutgalls produces a very copious brown coloured precipitate. Nitrate of silver occasions a white precipitate, which is insoluble in nitric acid, and consequently is muriate of silver†.

When slowly evaporated it becomes slightly milky, a transparent pellicle forms on its surface, and it leaves a residuum which does not exceed 0.012 of the whole. By lixiviating this residuum, and evaporating the ley, crystals of muriate and carbonate of soda may be obtained. The remainder, when incinerated, exhales a fetid and ammoniacal odour, resembling that of burning horn; the ashes consist of a small quantity of carbonate of soda, and of phosphate and carbonate of lime‡.

Thus we see that the liquor of the human amnios is composed of about

Composition.

\* *Ann. de Chim.* xxiii. 271.

† *Ibid.*

‡ *Ibid.* p. 272.

conjectured, that it is formed from the albumen of that liquid, which has undergone some unknown changes. It has been long known that the parts of a fœtus, which has lain for some time after it has been deprived of life in the uterus, are sometimes converted into a kind of fatty matter. It is evident that this substance, after it is deposited upon the skin of the fœtus, must preserve it in a great measure from being acted upon by the liquor of the amnios.

2. The liquor of the amnios of the cow\* has a viscid-ity similar to mucilage of gum arabic, a brownish red colour, an acid and bitter taste, and a peculiar odour, not unlike that of some vegetable extracts. Its specific gravity is 1.028. It reddens the tincture of turnsole, and therefore contains an acid. Muriate of barytes causes a very abundant precipitate, which renders it probable that it contains sulphuric acid. Alcohol separates from it a great quantity of a reddish coloured matter †.

Liquor of  
the amnios  
of the cow,

When this liquid is evaporated, a thick frothy scum gathers on the surface, which is easily separated, and in which some white acid-tasted crystals may be discovered. By continuing the evaporation, the matter becomes thick and viscid, and has very much the look of honey. Alcohol boiled upon this thick matter, and filtered off, deposits upon cooling brilliant needleform crystals nearly an inch in length. These crystals may be obtained in abundance by evaporating the liquor of

\* A minute account of the liquor amnii, and of the liquor alantoidis of the cow, has been published by Dzondi; for an abstract of which see Gehlen's Jour. Second Series, ii. 652.

† *Ann. de Chim.* xxxii. 275.



Book V.

the amnios to a fourth part of its bulk, and then allowing it to cool. The crystals soon make their appearance. They may be separated and purified by washing them in a small quantity of cold water. These crystals are *amniotic acid* \*.

If after the separation of this acid the liquor of the amnios be evaporated to the consistence of a syrup, large transparent crystals appear in it, which have all the properties of sulphate of soda. The liquid of the amnios of cows contains a considerable quantity of this salt.

Composition.

Thus it appears that the liquor of the amnios of cows contains the following ingredients :

1. Water
2. A peculiar animal matter
3. Acid
4. Sulphate of soda.

The animal matter possesses the following properties: It has a reddish brown colour and a peculiar taste; it is very soluble in water, but insoluble in alcohol, which has the property of separating it from water. When exposed to a strong heat it swells, exhales first the odour of burning gum, then of empyreumatic oil and of ammonia, and at last the peculiar odour of prussic acid becomes very conspicuous. It differs from gelatine in the viscosity which it communicates to water, in not forming a jelly when concentrated, and in not being precipitated by tannin. It must be therefore ranked among the very undefined and inaccurate class of *animal muciages*. When burnt it leaves a very large coal, which is readily incinerated, and leaves a little white ashes,

---

\* *Ann. de Chim.* xxiii, 276.



composed of phosphate of magnesia, and a very small proportion of phosphate of lime \*.

Chap. II.

## SECT. XXII.

### OF ANIMAL POISONS.

SEVERAL animals are furnished with liquid juices of a poisonous nature, which when poured into fresh wounds occasion the disease or death of the wounded animal. Serpents, bees, scorpions, spiders, are well known examples of such animals. The chemical properties of these poisonous juices deserve peculiar attention; because it is only from such an investigation that we can hope to explain the fatal changes which they induce on the animal economy, or to discover an antidote sufficiently powerful to counteract their baneful influence. Unfortunately the task is difficult, and perhaps surpasses our chemical powers. For the progress already made in the investigation, we are indebted almost entirely to the labours of Fontana.

1. The poison of the viper is a yellow liquid, which lodges in two small vesicles in the animal's mouth. These communicate by a tube with the crooked fangs, which are hollow, and terminate in a small cavity. When the animal bites, the vesicles are squeezed, and

Poison of  
the viper

\* *Ann. de Chim.* xxxiii. 272.

inflame till it has become black. These properties are similar to the properties of gum, and indicate the gummy nature of this poisonous substance. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results.

From the late observations of Dr Russel, there is reason to believe that the poisonous juices of the other serpents are similar in their properties to those of the viper.

This striking resemblance between gums and the poison of the viper, two substances of so opposite a nature in their effects upon the living body, is a humiliating proof of the small progress we have made in the chemical knowledge of these intricate substances. The poison of the viper, and of serpents in general, is most hurtful when mixed with the blood. Taken into the stomach it kills if the quantity be considerable. Fontana has ascertained that its fatal effects are proportional to its quantity, compared with the quantity of the blood. Hence the danger diminishes as the size of the animal increases. Small birds and quadrupeds die immediately when they are bitten by a viper; but to a full-sized man the bite seldom proves fatal.

Ammonia has been proposed as an antidote to the bite of the viper. It was introduced in consequence of the theory of Dr Mead, that the poison was of an acid nature. The numerous trials of that medicine by Fontana robbed it of all its celebrity; but it has been lately revived and recommended by Dr Ramsay as a certain cure for the bite of the rattlesnake\*.

Ammonia  
proposed as  
an antidote.

\* *Phil. Mag.* xvii.

The reader will find an interesting disserta-

Book V.  
Venom of  
the bee and  
wasp.

2. The venom of the bee and the wasp is also a liquid contained in a small vesicle forced through the hollow tube of the sting into the wound inflicted by that instrument\*. From the experiments of Fontana, we learn that it bears a striking resemblance to the poison of the viper. That of the bee is much longer in drying when exposed to the air than the venom of the wasp.

Of the scorpion,

3. The poison of the scorpion resembles that of the viper also. But its taste is hot and acrid, which is the case also with the venom of the bee and the wasp.

Of spiders.

4. No experiments upon which we can rely have been made upon the poison of the spider tribe. From the rapidity with which these animals destroy their prey, and even one another, we cannot doubt that their poison is sufficiently virulent†.

---

tion on the different remedies applied to the cure of the rattlesnake is the *Amer. Trans.* vol. iii. p. 100. by Dr Smith Barton. The observations of Fontana in his treatise on poisons deserve particular attention.

\* See a curious account of the structure of the sting by Dr Hooke in his *Micrographia*.

† Dr Mead's romantic account of the bite of the tarantula will entertain the reader. See Mead on *Poisons*, p. 57.

## SECT. XXIII.

THE AIR CONTAINED IN THE SWIMMING BLADDERS  
OF FISHES.

ANY fish are furnished with a bladder filled with air, means of which they are supposed to rise or sink in water. When they wish to rise they are supposed to dilate their air bladder; when they wish to sink they compress it. Whether this be the use of the air bladder of fishes is somewhat doubtful. Most fish have a peculiar depth at which they almost always remain, as the flat fish constantly affect the bottom of the sea, while there are others that as constantly affect the surface. From the late observations of Biot it appears, that when a fish is suddenly brought from a great depth towards the surface, the air bladder swells so much that the fish cannot again sink; nay, it often bursts; the air making its way into the stomach, swells it and forces it into the mouth or œsophagus. The air in which these bladders is filled was first examined by Dr Priestley in 1774. From his observations it appears that it varies in its nature. The roach was the first the air bladder of which he examined. At first he found it filled with azote, but afterwards he got a mixture of oxygen and azote\*.

History.

---

\* Priestley *On Air*, ii. 462.



## Book V.

Fourcroy long after examined the air in the air bladder of the carp, and found it almost pure azote; and similar results were obtained by other chemists. But by far the most complete analysis of this kind of air has been lately made by Biot, while in Yviza and Formentera, two islands a little to the south of Majorca and Minorca. He was employed by the French government to prolong the meridian of France to the Balearic islands, and embraced the opportunity which presented itself to examine the air in the bladders of the different species of fish caught in the neighbourhood of these islands. Next season he returned to the same islands with Mr Laroche, who repeated and confirmed his preceding experiments\*.

## Experiments of Biot.

Biot found the air in the air-bladders a mixture of azotic and oxygen gas in very variable proportions. No traces of hydrogen gas could be detected; nor was there any sensible quantity of carbonic acid. The proportion of oxygen gas was very various, being sometimes very minute, and sometimes constituting almost the whole of the gas. The air bladders of those fish which live near the surface contained least oxygen gas, and the bladders of those which were brought up from a great depth contained the most. The following Table exhibits the proportion of oxygen in 100 parts of the air in the different fish examined.

	Names of the Fish.	Proportion of Oxygen.
Proportion of oxygen.	Mugil cephalus ( <i>Linn.</i> ).....	Quantity insensible
	Ditto .....	Ditto
	Muraenophis helena ( <i>Lacepede</i> )...	Very little

\* Biot's Memoires are printed in the *Mém. D'Arcueil*, i. 252. and ii. 8

Names of the Fish.	Proportion of Oxygen.	Chap. II.
<i>Sparus annularis</i> ( <i>Linn.</i> ) female	0.09	}
Ditto male .....	0.08	
<i>Sparus sargus</i> ( <i>Linn.</i> ) female ....	0.09	
Ditto male .....	0.20	
<i>Holocentrus Marinus</i> ( <i>Lacepede</i> )	0.12	
<i>Labrus turdus</i> ( <i>Linn.</i> ) .....	0.16	
<i>Sparus melanurus</i> ( <i>Linn.</i> ) .....	0.20	
<i>Labrus turdus</i> ( <i>Var. Linn.</i> ) .....	0.24	
<i>Scizena nigra</i> , female .....	0.27	
Ditto male .....	0.25	
<i>Labrus turdus</i> ( <i>Linn.</i> ) female ...	0.24	
Ditto male .....	0.28	
<i>Sparus dentex</i> ( <i>Linn.</i> ) female ....	0.40	
<i>Sphyræna spet.</i> ( <i>Lacepede</i> ) .....	0.44	
<i>Sparus argenteus</i> .....	0.50	
<i>Sparus erythrinus</i> .....	Much	
<i>Holycentrus gigas</i> .....	0.69	
<i>Gadus merluccius</i> ( <i>Linn.</i> ) .....	0.79	
<i>Trygla lyra</i> ( <i>Linn.</i> ) .....	0.87	

The depth at which the fish in the preceding table are caught increases gradually, as well as the proportion of oxygen, from the beginning to the end of the table. The last mentioned fish, the trygla lyra is always caught at a very great depth. The experiments of Laroche confirm the accuracy of this curious fact. The mean result, furnished by all the fishes taken at a depth greater than 150 feet, was 0.70 of oxygen; while the mean result, furnished by the fish caught at less depths, was 0.29. This superior purity is not owing to any superior purity in the air of the water of the sea at great depths. The air obtained from sea water, brought up from a great

Book V. depth, yielded 0.265 of oxygen, while that from water taken at the surface was purer. .

It is very remarkable that the air in the bladder of fishes, taken near the surface, should be almost pure azote. But this holds also with respect to fresh water fish. Thus Biot found the air in the air bladder of a carp to contain 0.03 of oxygen, while that of a perch contained 0.16; and Geoffroy and Vauquelin found the air in the air-bladder of pikes, loaches, and perches, to contain 0.05 of oxygen. Humboldt likewise found very little oxygen in the air bladder of the gymnast electricus.

---

## SECT. XXIV.

### OF SWEAT.

A QUANTITY of matter is constantly emitted from the skin; this matter is invisible, and is distinguished by the name of *perspiration*. Several experiments were made by Lavoisier and Seguin to ascertain its amount. Mr Cruickshanks\* made numerous trials to determine its nature, and it has been lately subjected to a chemical examination by Thenard†.

---

\* Cruickshanks on *Insensible Perspiration*.

† *Ann. de Chim.* lix. 263.

1. Mr Cruickshanks put his hand into a glass vessel, Chap. II.  
 and luted its mouth at his wrist by means of a bladder. Water.  
 The interior surface of the vessel became gradually dim,  
 and drops of water trickled down. By keeping his  
 hand in this manner for an hour, he collected 30 grains  
 of a liquid, which possessed all the properties of pure  
 water\*. On repeating the same experiment at nine in  
 the evening (thermometer 62°), he collected only 12  
 grains. The mean of these is 21 grains. But as the  
 hand is more exposed than the trunk of the body, it  
 is reasonable to suppose that the perspiration from  
 it is greater than that from the hand. Let us there-  
 fore take 30 grains per hour as the mean; and let us  
 suppose, with Mr Cruickshanks, that the hand is  $\frac{1}{25}$ th  
 of the surface of the body: The perspiration in an hour  
 would amount to 1880 grains, and in 24 hours to 43,200  
 grains, or seven pounds six ounces troy. This is al-  
 most double of the quantity ascertained by Lavoisier  
 and Seguin. Hence we may conclude that more matter  
 is perspired through the hand than the other parts of  
 the body, provided Mr Cruickshanks's estimate of the  
 ratio between the surface of the hand and body be not  
 erroneous.

He repeated the experiment again after hard exercise,  
 and collected in an hour 48 grains of water†. He  
 found also, that this aqueous vapour pervaded his stock-  
 ing without difficulty; and that it made its way through  
 a shamoy leather glove, and even through a leather boot,  
 though in a much smaller quantity than when the leg  
 wanted that covering‡.

\* On *Invisible Perspiration*, p. 68.  
*Vol. V.*

† *Ibid.* p. 70.

‡ *Ibid.* p. 81.



Jurine found that air which had remained for some time in contact with the skin consisted almost entirely of carbonic acid gas\*. The same conclusion may be drawn from the experiments of Ingenhousz and Milly†. Troussset has lately observed that air was separated copiously from a patient of his while bathing‡.

Now it is evident that the carbonic acid gas which appeared during Mr Cruickshanks's experiment did not previously exist in the glass vessel; consequently it must have either been transmitted ready formed through the skin, or formed during the experiment by the absorption of oxygen gas, and the consequent emission of carbonic acid gas. The experiments of Mr Jurine do not allow us to suppose the first of these to be true; for he found that the quantity of air allowed to remain in contact with the skin did not increase. Consequently the appearance of the carbonic acid gas must be owing either to the emission of carbon, which forms carbonic acid gas by combining with the oxygen gas of the air, or to the absorption of oxygen gas, and the subsequent emission of carbonic acid gas; precisely in the same manner, and for the same reason, that these substances are emitted by the lungs. The last is the more probable opinion; but the experiments hitherto made do not enable us to decide.

3. Besides water and carbon, or carbonic acid gas, the skin emits also a particular odorous substance. That every animal has a peculiar smell, is well known: the dog can discover his master, and even trace him to a

3. An oily matter.

\* *Encyc. Meth. Med.* i. 515.

† *Ibid.* p. 516.

‡ *Ann. de Chim.* xlv. 73.

were clean flannel-waistcoats next their skin for ten days; the waistcoats had been first washed with soap, then in pure water, then in water acidulated with muriatic acid, and lastly in a great quantity of pure water. He steeped the waistcoats in hot distilled water, and thus separated from them the perspired matter. The liquid was put into a retort, and concentrated to the consistence of a syrup. The liquid which came over had a disagreeable smell, and reddened infusion of litmus. Kept in an open vessel it retained its transparency, but lost its odour. The residue in the retort had no smell. It was strongly acid, and tasted distinctly of common salt, while at the same time an acrid and hot flavour could be distinguished. When evaporated to dryness and strongly heated, the acid which it contained was dissipated or destroyed, and the residue consisted of common salt, charcoal, and minute traces of phosphate of lime, and oxide of iron. The same destruction of the acid took place if it was previously saturated with potash before it was heated to redness, and in that case the potash was converted into a carbonate. When saturated with an alkali, and distilled along with phosphoric acid, it yielded an acid which possessed all the characters of the acetic<sup>a</sup>.

5. The small quantity of animal matter which Thenard found in the perspired matter, possessed characters which induced him to consider it as similar to gelatine in its nature.

5. Animal matter.

Fourcroy and Vauquelin have ascertained that the scurf which collects on the skins of horses consists chief-

---

<sup>a</sup> Thenard, *Ann. de Chim.* lix. 263.

Book V.

ly of phosphate of lime, and urea is even sometimes mixed with it.

Such are the constituents of *perspired matter*. Though the sweat has not been directly analysed, there is every reason to believe that it is composed of similar constituents.

---

## SECT. XXV.

### OF URINE.

History.

No animal substance has attracted more attention than urine, both on account of its supposed connection with various diseases, and on account of the very singular products which have been obtained from it. Mr Boyle, and the other chemists who were his contemporaries, were induced to attend particularly to this liquid, by the discovery of a method of obtaining phosphorus from it. Boerhaave, Haller, Haupt, Margraff, Pott, Rouelle, Proust, and Klaproth, successively improved the method of obtaining the phosphoric salts from urine, or added something to our knowledge of the component parts of these salts. Scheele added greatly to our knowledge of urine by detecting several new substances in it which had not been suspected. Cruickshanks has given us a very valuable paper on urine in the second edition of *Rollo's Diabetes*. Fourcroy and Vauquelin have lately published a very complete analysis of it; and Mr Proust has published another, no less ingenious,



in which he points out the existence of several substances which had been overlooked by other chemical philosophers.

Chap. II.

Fresh urine differs considerably in its appearance according to the state of the person and the time at which it is voided. In general, healthy urine is a transparent liquid of a light amber colour, an aromatic odour resembling that of violets, and a disagreeable bitter taste. Its specific gravity varies, according to Mr Cruickshanks, from 1.005 to 1.033. When it cools, the aromatic smell leaves it, and is succeeded by another, well known by the name of *urinous smell*. This smell is succeeded in two or three days by another, which has a considerable resemblance to that of sour milk. This smell gradually disappears in its turn, and is succeeded by a fetid alkaline odour.

Properties.

1. Urine reddens paper stained with turnsole and with the juice of radishes, and therefore contains an acid. This acid has been generally considered as the phosphoric; but Thenard has shown that it is in reality the acetic\*.

Contains an acid,

2. If a solution of ammonia be poured into fresh urine, a white powder precipitates, which has the properties of phosphate of lime. The presence of this substance in urine was first discovered by Scheele†. The phosphate of lime is obviously kept in solution by the acetic acid. Scheele affirms that it is most abundant in the urine of the sick. Berthollet has observed, that the urine of gouty people is more acid than that of people in perfect health. The average quantity of phos-

Phosphate of lime,

\* *Ann. de Chim.* lix. 269.

† Scheele, i. 208.



Book V.

Phosphate  
of magnesia,Carbonic  
acid,Carbonate  
of lime,

Uric acid,

phate of lime in healthy urine is, as Cruickshank has ascertained, about  $\frac{1}{500}$  of the weight of the urine \*.

3. If the phosphate of lime precipitated from urine be examined, a little magnesia will be found mixed with it. Fourcroy and Vauquelin have ascertained that this is owing to a little phosphate of magnesia which urine contains, and which is decomposed by the alkali or lime employed to precipitate the phosphate of lime †.

4. Proust informs us that carbonic acid exists in urine, and that its separation occasions the froth which appears during the evaporation of urine ‡. Fourcroy and Vauquelin, on the other hand, consider this acid as formed during the evaporation by the decomposition of the urea. The observations of Proust confirm those that had been made by Priestley and Percival.

5. Proust has observed, that urine kept in new casks deposits small crystals which effloresce in the air and fall to powder. These crystals possess the properties of carbonate of lime §. Hence we must conclude that urine contains carbonate of lime; a very extraordinary fact, if we reflect that acetic acid is also present.

6. When fresh urine cools, it often lets fall a brown-coloured precipitate, which Scheele first ascertained to be crystals of uric acid. All urine contains this acid, even when no sensible precipitate appears when it cools. For, if a sufficient quantity of clear and fresh urine be evaporated to  $\frac{1}{100}$  of its weight, a subtile powder ap-

\* *Phil. Mag.* ii. 241.

† *Ann. de Chim.* xxii. 66.—The same discovery had been previously made by Dr Wollaston. See his examination of calculi, *Phil. Trans.* 1797.

‡ *Ann. de Chim.* xxvi. 260.

§ *Ibid.* p. 263.

precipitates to the bottom, and attaches itself in part very firmly to the vessel. This part may be dissolved in pure alkali, and precipitated again by acetic acid. It exhibits all the properties of uric acid \*. The fact is, that the precipitate which usually falls when urine cools consists chiefly of phosphate of lime and uric acid. It may be dissolved in diluted nitric acid. If the solution be heated and evaporated to dryness, it assumes a fine rose colour if uric acid be present †. The proportion of uric acid varies considerably in urine. It crystallizes in small red prisms, partly on the surface, if urine be mixed with some nitric acid, and left exposed to the air. Indeed, from the late ingenious experiments of Dr Egan, we learn that all acids when mixed with urine throw down uric acid in crystals ‡.

7. During intermittent fevers, and especially during diseases of the liver, a copious sediment of a brick red colour is deposited from urine. This sediment contains the rosacic acid of Proust.

Rosacic  
acid,

8. If fresh urine be evaporated to the consistence of a syrup, and muriatic acid be then poured into it, a precipitate appears which possesses the properties of benzoic acid. Scheele first discovered the presence of benzoic acid in urine. He evaporated it to dryness, separated the saline part, and applied heat to the residuum. The benzoic acid was sublimed, and found crystallized in the receiver. The above method was first proposed by Fourcroy and Vauquelin §. By it very considerable quantities of benzoic acid may be obtained from the

Benzoic  
acid,

\* Scheele, i. 207.

† *Phil. Mag.* xliii. 298.

‡ Cruickshank.

§ *Ann. de Chim.* xlii. 61.

Book V.

urine of horses and cows, where it is much more abundant than in human urine. In human urine it varies from  $\frac{1}{10000}$  to  $\frac{1}{100000}$  of the whole \*. Proust affirms that the acid obtained by Scheele's process is not the benzoic, but another possessed of similar properties; but differing in this circumstance, that nitric acid decomposes it, whereas it only whitens benzoic acid †.

9. When an infusion of tannin is dropt into urine, a white precipitate appears, having the properties of the combination of tannin and albumen, or gelatine. Urine, therefore, contains albumen or gelatine. These substances had been suspected to be in urine, but their presence was first demonstrated by Seguin, who discovered the above method of detecting them. Their quantity in healthy urine is very small, often indeed not sensible. Cruickshanks found that the precipitate afforded by tannin in healthy urine amounted to  $\frac{1}{125}$ th part of the weight of the urine ‡. It is to these substances that the appearance of the *cloud*, as it is called, or the mucilaginous matter, which is sometimes deposited as the urine cools, is owing. In many diseases the quantity of these matters is very much increased. The urine of dropsical people often contains so much albumen, that it coagulates not only on the addition of acids, but even on the application of heat §. In all cases of impaired digestion, the albuminous part of urine is much increased. This forms one of the most conspicuous and important distinctions between the urine of those who enjoy good and bad health ||.

Albumen  
and gela-  
tine,

\* *Ann. de Chim.* xxxi. 63.† *Ibid.* xxvi. 273.‡ *Phil. Mag.* ii. 243.§ Cruickshanks, *Ibid.* 241.|| Fourcroy and Vauquelin, *Ann. de Chim.* xxxi. 62.



10. If urine be evaporated by a slow fire to the consistence of a thick syrup, it assumes a deep brown colour, and exhales a fetid ammoniacal odour. When allowed to cool, it concretes into a mass of crystals, composed of all the component parts of urine. If four times its weight of alcohol be poured upon this mass, at intervals, and a slight heat be applied, the greatest part of it is dissolved. The alcohol, which has acquired a brown colour, is to be decanted off, and distilled in a retort in a sand heat, till the mixture has boiled for some time, and acquired the consistence of a syrup. By this time the whole of the alcohol has passed off, and the matter, on cooling, crystallizes in quadrangular plates which intersect each other. This substance is *urea*, which composes  $\frac{1}{6}$  of the urine, provided the watery part be excluded. To this substance the taste and smell of urine are owing. It is a substance which characterizes urine, and constitutes it what it is, and to which the greater part of the very singular phenomena of urine are to be ascribed.

Chap. II.

Urea,

It may be detected by evaporating urine to the consistence of a syrup, and pouring into it concentrated nitric acid. Immediately a great number of white shining crystals appear in the form of plates, very much resembling crystallized boracic acid. These crystals are *urea* combined with nitric acid.

The quantity of *urea* varies exceedingly in different cases. In the urine voided soon after a meal, very little of it is to be found, and scarcely any at all in that which hysterical patients void during a paroxysm.

11. According to Fourcroy and Vauquelin, the colour of urine depends upon the *urea*: the greater the proportion of *urea*, the deeper the colour. But Proust

Resin,



Book V. has detected a resinous matter in urine, similar to the resin of bile; and to this substance he ascribes the colour of urine. If urine, evaporated to the consistence of an extract, be mixed with sulphuric acid and distilled, this resin, he informs us, separates during the distillation. What is first obtained is soft, but the last portions are in a state of a dry powder. The consistence and colour of this resin resemble castor: it is very soluble in alcohol, and precipitated from its solution by water: but it is also soluble in water; and, according to Proust, is the resin of bile, somewhat modified by its passage through the urinary organs\*.

Muriate of soda,

12. If urine be slowly evaporated to the consistence of a syrup, a number of crystals make their appearance on its surface: these possess the properties of muriate of soda. Urine therefore contains muriate of soda. It is well known that muriate of soda crystallizes in cubes; but when obtained from urine it has the form of octahedrons. This singular modification of its form is owing to the action of urea†. It has been long known that urine saturated with muriate of soda deposits the salt in regular octahedrons.

Phosphate of ammonia and of soda,

13. The saline residuum which remains after the separation of urea from crystallized urine by means of alcohol has been long known by the names of *fossele of urine* and *microcosmic salt*. Various methods of obtaining it have been given by chemists, from Boerhaave, who first published a process, to Rouelle and Chauliès, who gave the method just mentioned. If this saline mass be dissolved in a sufficient quantity of hot water,

\* *Ann. de Chim.* xxvi. 274.

† Fourcroy and Vauquelin.

and allowed to crystallize spontaneously in a close vessel, two sets of crystals are gradually deposited. The lowermost set has the figure of flat rhomboidal prisms; the uppermost, on the contrary, has the form of rectangular tables. These two may be easily separated by exposing them for some time to a dry atmosphere. The rectangular tables effloresce and fall to powder, but the rhomboidal prisms remain unaltered.

When these salts are examined, they are found to have the properties of phosphates. The rhomboidal prisms consist of phosphate of ammonia united to a little phosphate of soda; the rectangular tables, on the contrary, are phosphate of soda united to a small quantity of phosphate of ammonia. Urine, then, contains phosphate of soda and phosphate of ammonia.

14. When urine is cautiously evaporated, a few cubic crystals are often deposited among the other salts; these crystals have the properties of muriate of ammonia. Now the usual form of the crystals of muriate of ammonia is the octahedron. The change of its form in urine is produced also by urea. This salt is obtained in greater abundance when the crystals of urea obtained from the alcohol solution are distilled\*.

Muriate of ammonia,

15. When urine is boiled in a silver basin, it blackens the basin; and if the quantity of urine be large, small crusts of sulphuret of silver may be detached. Hence we see that urine contains sulphur. This sulphur exhales along with the carbonic acid when the urine putrefies; for the fumes which separate from

Sulphur,

---

\* Fourcroy and Vauquelin.

Book V. urine in that state blacken paper stained with acetated lead \*.

Constitu-  
ents.

Urine, then, contains the following substances :

- |                          |                          |
|--------------------------|--------------------------|
| 1. Water                 | 10. Albumen              |
| 2. Acetic acid           | 11. Urea                 |
| 3. Phosphate of lime     | 12. Resin                |
| 4. Phosphate of magnesia | 13. Muriate of soda      |
| 5. Carbonic acid         | 14. Phosphate of soda    |
| 6. Carbonate of lime     | 15. Phosphate of ammonia |
| 7. Uric acid             | 16. Muriate of ammonia   |
| 8. Rosacic acid          | 17. Sulphur.             |
| 9. Benzoic acid          |                          |

Substances  
occasionally  
present.

These are the only substances which are constantly found in healthy urine † ; but it contains also occasionally other substances. Very often muriate of potash may be distinguished among the crystals which form during its evaporation. The presence of this salt may always be detected by dropping cautiously some tartaric acid into urine. If it contains muriate of potash, there will precipitate a little tartar, which may easily be recognized by its properties ‡.

Urine sometimes also contains sulphate of soda, and even sulphate of lime. The presence of these salts may be ascertained by pouring into urine a solution of muriate of barytes ; a copious white precipitate appears, consisting of the barytes combined with phosphoric acid, and with sulphuric acid, if any be present. This precipitate must be treated with a sufficient quantity of

\* Proust, *Ann. de Chim.* xxxvi. 258.

† Fourcroy and Vauquelin, *Ibid.* xxxi. 69.

‡ Cruickshanks, *Phil. Mag.* ii. 247.



muric acid. The phosphate of barytes is dissolved, but the sulphate of barytes remains unaltered \*.

Chap. II.

No substance putrefies sooner, or exhales a more detestable odour, during its spontaneous decomposition, than urine; but there is a very great difference in this respect in different urines. In some, putrefaction takes place almost instantaneously as soon as it is voided; in others, scarcely any change appears for a number of days. Fourcroy and Vanquelin have ascertained that this difference depends on the quantity of gelatine and albumen which urine contains. When there is very little of these substances present, urine remains long unchanged; on the contrary, the greater the quantity of gelatine or albumen, the sooner does putrefaction commence. The putrefaction of urine, therefore, is in some degree the test of the health of the person who has voided it: for a superabundance of gelatine in urine always indicates some defect in the power of digestion †.

Putrefaction of urine.

The rapid putrefaction of urine, then, is owing to the action of gelatine on urea. We have seen already the facility with which that singular substance is decomposed, and that the new products into which it is changed are, ammonia, carbonic acid, and acetic acid. Accordingly, the putrefaction of urine is announced by an ammoniacal smell. Mucilaginous flakes are deposited, consisting of part of the gelatinous matter. The phosphoric acid is saturated with ammonia, and the phosphate of lime, in consequence, is precipitated. Ammonia combines with the phosphate of magnesia, forms

\* Fourcroy, *Ann. de Chim.* vii. 183.

† *Id.* *Ibid.* xxi. 61.



the acids contained in urine are saturated with ammonia, and the gelatine and phosphate of lime precipitate \*.

Chap. II.

SUCH are the properties of human urine in a state of health: But this excretion is singularly modified by disease; and the changes to which it is liable have attracted the attention of physicians in all ages, because they serve in some measure to indicate the state of the patient, and the progress of the disease under which he labours. The following are the most remarkable of these changes that have been observed †.

Changes in  
it by dis-  
ease.

1. In *inflammatory* diseases the urine is of a red colour, and peculiarly acrid; it deposits no sediment on standing, but with oxymuriate of mercury it yields a copious precipitate.

Inflamma-  
tion.

2. During *jaundice* the urine has an orange yellow colour, and communicates the same tint to linen. Muriatic acid renders this urine green, and thus detects the presence of a little bile.

Jaundice.

From the experiments of Fourcroy and Vauquelin, we learn that urine sometimes in these cases contains a substance analogous to the yellow acid which they formed by the action of nitric acid on muscular fibres ‡.

3. About the end of *inflammatory* diseases the urine becomes abundant, and deposits a copious pink-coloured sediment, composed of rosadic acid, a little phosphate of lime, and uric acid.

End of In-  
flammation.

4. During *hysterical* paroxysms the urine usually

Hysteria.

\* *Ann. de Chim.* xxxi. 55.

† See Cruickshanks, *Phil. Mag.* ii. 249.; and Fourcroy, 2, 166.

‡ *Phil. Mag.* xliii. 331.

the urine of other animals differs considerably from that of man. For the analysis of the urine of quadrupeds hitherto made, we are chiefly indebted to Rouelle and Berthollet. The following facts have been ascertained by Berthollet, and by the late experiments of Fourcroy and Vauquelin, Brande, and Chevreul.

Chap. II.

Urine of inferior animals.

The urine of the HORSE has a peculiar odour: after exercise it is emitted thick and milky; at other times it is transparent, but becomes muddy soon after emission. When exposed to the air, its surface becomes covered with a crust of carbonate of lime. It turns a green colour to syrup of violets, and has the consistence of mucilage. The following are its constituents, as estimated by Fourcroy and Vauquelin from experiments:

The horse.

Carbonate of lime .....	0.011
Carbonate of soda .....	0.009
Benzoate of soda .....	0.024
Muriate of potash .....	0.009
Urea .....	0.007
Water and mucilage ....	0.940

1.000 \*

The urine of the horse has been lately analysed by Berthollet and Brande. The salts which it contains are, according to them, the following:

Diabetic urine by Nicolas, *Ann. de Chim.* xlv. 32.; the analysis of the urine by Sorg (*Gehlen's Jour.* vi. 9.), and by Dupuytren and Berthollet (*Ann. de Chim.* lxx. 41.)  
*Mem. de l'Inst.* ii. 431.

## ANIMAL FLUIDS.

Carbonate of lime

Carbonate of soda

Sulphate of soda

Muriate of soda

Benzoate of soda

Phosphate of lime

These saline substances amount to about  $\frac{1}{10}$ th of the urine \*. The urine of the horse has been recently subjected to a new examination by Chevreul expressly to ascertain whether it contained phosphate of lime announced in it by Brande. His experiments confirmed those of Fourcroy and Vauquelin. The urine yielded no traces of phosphate of lime; but it contained magnesia and sulphate of potash, neither of which substances had been observed by Mr Brande †.

From the late experiments of Mr Giese, we learn that the quantity of benzoate of soda varies considerably in the urine of horses. In some specimens he found it in abundance, and easily precipitated by muriatic acid. In others there was little or none. He could detect no benzoic acid in the food of horses. Hence he considers it as formed within the animal, and he thinks that it appears only in cases of disease ‡.

The ass.

II. The urine of the ASS was likewise examined by Mr Brande. It is transparent, but mucilaginous. It gives a green colour to syrup of violets, but no carbonate of lime is deposited from it on standing. It contains, according to Brande, urea, more phosphate of lime than the urine of the horse, carbonate of soda, sulphate of

\* *Ann. de Chim.* lxxvii. 276.† *Ibid.* 303.‡ *Phil. Mag.* xvii. 151.

soda, muriate of soda, and probably muriate of potash. Chap. II.

It contains no ammonia \*.

III. The urine of the cow has a strong resemblance The cow. to that of the horse; it has nearly the same odour, and the same mucilaginous consistence. It tinges syrup of violets green, and deposits a gelatinous matter. On standing, small crystals are formed on its surface. It contains, according to Rouelle,

- |                        |                 |
|------------------------|-----------------|
| 1. Carbonate of potash | 4. Benzoic acid |
| 2. Sulphate of potash  | 5. Urea.        |
| 3. Muriate of potash   |                 |

The urine of the cow has been recently examined by Mr Brande. He found it composed of the following constituents :

Water .....	65
Phosphate of lime .....	3
Muriate of potash	} .....
Muriate of ammonia	
Sulphate of potash .....	15
Carbonate of potash	} .....
Carb. of ammonia	
Urea .....	4
Loss .....	3
	100

He obtained from it likewise a quantity of benzoic acid, but conceives that this acid was formed during the process†.

IV. The urine of the CAMEL was also examined by The camel. Rouelle. Its odour resembles that of the urine of the

\* *Ann. de Chim.* lxxv. 277.

† *Ibid.* 268.



Book V.

cow ; its colour is that of beer ; it is not mucilaginous, and does not deposit carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acid like the urine of the horse and cow. Rouelle obtained from it,

- |                        |                      |
|------------------------|----------------------|
| 1. Carbonate of potash | 9. Muriate of potash |
| 2. Sulphate of potash  | 4. Urea              |

This urine has been recently examined by Mr Brande \*. He obtained from it the following substances :

Water .....	75
Phosphate of lime	} ..... 6
Muriate of ammonia	
Sulphate of potash	
Urate of potash	
Carbonate of potash	
Muriate of potash .....	8
Urea .....	6
Loss .....	5
	<hr/> 100

Chevreul subjected the urine of the camel to a rigid examination, on purpose to ascertain whether it really contained the phosphate of lime announced as a constituent of it by Mr Brande. He could detect none of it whatever, but separated from the urine of the camel the following substances :

Albumen  
Carbonate of lime  
Carbonate of magnesia

---

\* *Ann. de Chim.* lxxii. 266.

## Silica

An atom of sulphate of lime

A trace of iron

Carbonate of ammonia

A little muriate of potash

A little sulphate of soda

Much sulphate of potash

A little carbonate of potash

Benzoic acid

## Urea

A red oil, to which the urine owes its smell and colour.

The last substance, the oil, seems to have been taken by Brande for uric acid \*.

V. The urine of the RABBIT has been lately analysed by Vauquelin. When exposed to the air, it becomes milky, and deposits carbonate of lime. It gives a green colour to syrup of violets, and effervesces with acids. That chemist detected in it the following substances :

- |                          |                      |
|--------------------------|----------------------|
| 1. Carbonate of lime     | 6. Muriate of potash |
| 2. Carbonate of magnesia | 7. Urea              |
| 3. Carbonate of potash   | 8. Gelatine          |
| 4. Sulphate of potash    | 9. Sulphur.          |
| 5. Sulphate of lime      |                      |

VI. Vauquelin has also made some experiments on the urine of the GUINEA PIG; from which it appears that it resembles the urine of the other quadrupeds. It deposits carbonate of lime, gives a green colour to syrup of violets, and contains carbonate and muriate of potash, but no phosphate nor uric acid †.

\* *Ann. de Chim.* lxxv. 294.

† *Pourcroy*, x. 181.

Book V.  
Fowls

VII. From the late experiments of Fourcroy and Vauquelin, we learn that the urine of domestic fowls contains uric acid \*.

The existence of that acid in the urine of fowls was called in question by Gehlen ; but it has been fully confirmed by the late experiments of Chevreul †.

Thus it appears that the urine of the graminivorous quadrupeds agrees with the human in containing urea, but differs from it materially in being destitute of phosphoric acid, phosphates, and uric acid. Whether the urine of carnivorous quadrupeds contains these last substances has not been ascertained, but it is probable that it does.

---

## SECT. XXIV.

### OF FECES.

THE excrementitious matter of animals, evacuated *per anum*, consists of all that part of the food which cannot be employed for the purposes of nutrition, considerably altered, at least in part, and mixed or united with various bodies employed during digestion to separate the

---

\* *Jour. de Phys.* liz. 66.

† *Ann. de Chim.* lxxv. 355.

useless parts of the food from the nutritious. An accurate examination of these matters has long been wished for by physiologists, as likely to throw much new light on the process of digestion. For if we knew accurately the substances which were taken into the body as food, and all the new substances which were formed by digestion; that is to say, the component parts of chyle and of excrement, and the variation which different kinds of food produce in the excrement, it would be a very considerable step towards ascertaining precisely the changes produced on food by digestion.

Some of the older chemists had turned their attention to the excrements of animals\*; but no discovery of importance rewarded them for their disagreeable labour. Vauquelin has ascertained some curious facts respecting the excrementitious matter of fowls. In the summer of 1806, a laborious set of experiments on human feces was published by Berzelius, undertaken, as he informs us, chiefly with a view to elucidate the function of digestion†. About two years before, Thær and Einhof had published a similar set of experiments on the excrements of cattle; made chiefly to discover, if possible, how they act so powerfully as manure‡. I shall in this Section give a view of the results obtained by these different chemists.

I. The appearance of human feces requires no particular detail. Their colour is supposed to depend upon the bile mixed with the food in the alimentary canal. When too light, it is supposed to denote a de-

Human  
feces.

\* Van Helmont's *Custos Errans*. Sect. vi.—*Opera Helmonti*. p. 247.—*Neumann's Works*, p. 385.

† Gehlen's *Jour.* vi. 309.

‡ *Ibid.* iii. 276.



Book V.

fiency of bile ; when too dark, there is supposed to be a redundancy of that secretion. The smell is foetid and peculiar, which after some time gradually changes into a sourish odour. The taste is sweetish bitter. The colour of vegetable blue infusions is not altered by fresh feces, indicating the absence of any uncombined acid or alkali \*.

1. The consistency of human feces varies considerably in different circumstances ; but at a medium, they may be stated to lose three-fourths of their weight when dried upon a water bath †.

Constitu-

2. They do not mix readily with water ; but by sufficient agitation and maceration, they may be diffused through it. The liquid, in this state, being strained through a linen cloth, leaves a matter of a greyish brown colour, retaining a peculiar odour, which adheres long and obstinately to all those substances that come in contact with this residue. When dried, this substance exhibits the remains of vegetable matters used in food, and perhaps also of some animal matters. Its quantity amounts to about seven *per cent.* of the feces ‡.

3. The strained liquid deposited, on standing, a yellowish-green slimy matter, which was separated by the filter. It amounted when dry to 14 *per cent.* of the feces employed. From the numerous experiments of Berzelius upon this matter, it appears to be composed chiefly of three substances : 1. A fatty matter, separated by means of alcohol, which possesses many properties in common with the resin of bile, and which

\* Gehlen's *Jour.* vi. 512.† *Ibid.* vi. p. 515.‡ *Ibid.* p. 513.

Berzelius considers as that substance a little altered.

2. A peculiar yellow-coloured substance, dissolved by water after the fatty matter is removed. This substance Berzelius compares to gelatine; but it appears to be rather more closely allied to mucus, or, at least, to contain mucus as a constituent. It dissolves in water, but not in alcohol; tannin makes its solution muddy, but occasions no precipitate; acetate of lead occasions a copious white precipitate, but does not deprive the solution of its yellow colour. It soon runs to putrefaction, exhaling the odour of putrid urine.

3. A greenish grey residue, insoluble both in water and alcohol, and leaving, when incinerated, some silica and phosphate of potash\*.

4. The liquid which passed through the filter was at first light yellow; but by exposure to the air it became brown, which gradually deepened in colour, till the solution grew at last muddy. When concentrated by evaporation, small transparent crystals made their appearance: which proved, on examination, to be crystals of ammonio-phosphate of magnesia. The solution, on examination, was found to contain the following substances: 1. Albumen, which was obtained by mixing the concentrated solution with alcohol. The precipitate consisted of a mixture of albumen and phosphoric salts. The albumen obtained from 100 parts of feces amounted only to 0.9 parts. 2. Bile. By this Berzelius understood a mixture of resin of bile and soda. The presence of this substance was inferred from the nature of the precipitate obtained by acids, and the salt

---

\* Gehlen's Jour. vi. 526—534.

Soda V.

of soda obtained by evaporating the residue. The quantity contained in 100 parts of feces was 0.9. 3. A peculiar substance, of a reddish brown colour, soluble both in water and alcohol. Acids give it an intense brown colour. A small quantity of tannin throws it down of a red colour and in a pulverulent form; a large quantity throws it down in greyish brown flakes. It is precipitated by muriate of tin, nitrate of silver, and acetate of lead. When heated it melts and emits the smell of ammonia. It leaves behind it, when burnt, traces of soda and of phosphoric salts. Berzelius supposes that this substance is formed from the resin of bile, by some change which it undergoes after the feces are exposed to the air. The quantity of it obtained from 100 parts of feces was 2.7 parts. 4. Various salts: These in all, from 100 parts of feces (including the ammonio-phosphate of magnesia), amounted to 1.2 parts. Their relative proportions were as follows:

Carbonate of soda .....	35
Muriate of soda .....	4
Sulphate of soda .....	2
Amm-phosphate of magnesia ..	2
Phosphate of lime .....	4

Such are the constituents of human feces, according to the experiments of Berzelius. The following Table exhibits the result of his analysis\*.

---

\* *Gehlen's Jour.* vi. 536.



Water .....	73.3
Vegetable and animal remains .....	7.0
Bile .....	0.9
Albumen.....	0.9
Peculiar extractive matter .....	2.7
Salts .....	1.2
Slimy matter ; consisting of resin of bile, peculiar animal matter, and insoluble residue.....	14.6
	<hr/> 100.0

II. The excrementitious matter examined by Thaer and Einhof was that of cattle fed at the stall, chiefly on turnips. It had a yellowish green colour, a smell somewhat similar to that of musk, and but little taste. Its specific gravity was 1.045. It did not alter vegetable blues, and of course contained no uncombined acid or alkali.

Feces of  
cattle.

1. Sulphuric acid, when mixed with this matter, develops the odour of acetic acid ; but Thaer and Einhof have shown that this acid does not exist in the feces, but is formed by the action of the sulphuric acid. The pure alkalies, nitric and muriatic acids, produce little change on the feces of cattle, at least when not assisted by heat.

2. When 100 parts are dried on a steam bath, they leave  $28\frac{1}{2}$  of solid matter.

3. When eight ounces, or 3840 grains, were diffused through water, they let fall a quantity of sand, weighing 45 grains.

4. The watery solution, being strained through a linen cloth, left 600 grains of a yellowish fibrous matter,



Book V.

which possessed the properties of the fibrous matter of plants \*.

5. The liquid, on standing, deposited a slimy substance, which was separated by filtration. It weighed when dry 480 grains. To this matter the feces owe their peculiar colour and smell. It was insoluble in water and alcohol. When heated it smelled like ex bile. It burnt like vegetable matter. Alkalies scarcely affected it. Sulphuric acid developed the odour of acetic acid. Oxymuriatic acid rendered it yellow. Thaer and Einhof considered this substance as the remains of the vegetable matter employed as food by the cattle; but it is extremely probable that it might contain also a portion of the resin of bile, as Berzelius detected that substance in a similar matter from the human feces.

6. The filtered solution passed through colourless, but on exposure to the air became in a few minutes wine yellow and then brown. When evaporated to dryness it left a brownish matter, of a bitterish taste, and weighing 90 grains. It was soluble in water, insoluble in alcohol, and precipitated from water by that liquid. It was not precipitated by infusion of galls. The solution was found to contain some phosphoric salts. The 90 grains of residue, when heated, burnt like animal matter. They soon ran into putrefaction, exhaling ammonia †.

7. When evaporated to dryness and burnt, this excrementitious matter left behind it an ash, which was

---

\* Gahlen, iii. 236.

† Gahlen, iii. 237.

found (not reckoning the sand) to consist of the following salts and earths in the proportion stated \* :

Chap. II.

Lime .....	12
Phosphate of lime .....	12·5
Magnesia .....	2
Iron .....	5
Alumina with some manganese	14
Silica .....	52
Muriate and sulphate of potash	1·2

8. Thaer and Einhof made numerous experiments on the putrefaction of cow dung, both in close vessels and in the open air, from which it would appear that the process resembles closely the putrefaction of vegetable matter; the oxygen of the air being abundantly changed into carbonic acid †.

III. To Vauquelin we are indebted for an analysis of the fixed parts of the excrements of fowls, and a comparison of them with the fixed parts of the food; from which some very curious consequences may be deduced.

*Excrements  
of fowls.*

He found that a hen devoured in ten days 11111·843 grains troy of oats. These contained

126·509 grains phosphate of lime  
219·548 silica

---

356·057

During these ten days she laid four eggs; the shells of which contained 98·776 grains phosphate of lime, and 453·417 grains carbonate of lime. The excrements emitted during these ten days contained 175·529 grains phosphate of lime, 58·494 grains of carbonate of lime,

\* Gehlen, iii. 321.

† Gehlen, iii. 295, 313.

had disappeared ; but if so, it must be combined with a great quantity of some other substance \*.

These consequences are too important to be admitted without a very rigorous examination. The experiment must be repeated frequently, and we must be absolutely certain that the hen has no access to any calcareous earth, and that she has not diminished in weight ; because in that case some of the calcareous earth, of which part of her body is composed, may have been employed. This rigour is the more necessary, as it seems pretty evident, from experiments made long ago, that some birds at least cannot produce eggs unless they have access to calcareous earth. Dr Fordyce found, that if the canary bird was not supplied with lime at the time of her laying, she frequently died, from her eggs not coming forward properly †. He divided a number of these birds at the time of their laying eggs into two parties : to the one he gave a piece of old mortar, which the little animals swallowed greedily ; they laid their eggs as usual, and all of them lived ; whereas many of the other party, which were supplied with no lime, died ‡.

Vauquelin also ascertained, according to Fourcroy, that pigeons dung contains an acid of a peculiar nature, which increases when the matter is diluted with water ; but gradually gives place to ammonia, which is at last exhaled in abundance §.

IV. The white matter voided by dogs who feed chiefly on bones, was formerly used in medicine under

\* *Ann. de Chim.* xxix. 61.

† *Ibid.* p. 26.

‡ *On Digestion*, p. 25.

§ Fourcroy, i. 79.



3. Biliary calculi
4. Urinary calculi
5. Gouty calculi

We shall take a view of each of these classes in order.

# I. OSSEIFICATIONS.

ALL the concretions which make their appearance in the solids of the animal body may be comprehended under this title with propriety ; because they have all a close resemblance to bone, being composed of similar constituents. The following are the most remarkable of these concretions.

1. *Pineal concretions*.—It is well known to anatomists that small concretions like sand are often found lodged in that part of the brain called the *pineal gland*. It was suspected from analogy that they consisted chiefly of phosphate of lime ; but Dr Wollaston was the first who examined them chemically, and proved the truth of this opinion. He dissolved some of the sand in nitric acid, and evaporated the solution ; small crystalline needles made their appearance, indicating the presence of phosphate of lime\*.

1. Pineal concretions.

2. *Salivary concretions*.—Small concretions occasionally make their appearance in the salivary glands, especially the parotid and sublingual. From the experi-

2. Salivary concretions.

\* See Dr Wollaston's important paper on Urinary and Gouty Concretions, *Phil. Trans.* 1797, p. 386.—I shall have occasion to refer to it very frequently in the subsequent part of this Section.



some cases they appear to contain no phosphate. Thus a pulmonary calculus examined by Mr Crumpton\* was composed of

Chap. II.

Carbonate of lime .....	82
Animal matter and water ..	18
	<hr/>
	100

5. *Hepatic concretions.*—The liver also is sometimes full of similar bodies. The shape of the hepatic concretions, as far as my observations go, is more irregular, and I have seen them of greater size, than the pulmonary concretions. By my analysis, they are composed of phosphate of lime and a tough animal membranous matter.

5. Hepatic concretions.

6. *Concretions in the prostate.*—From the experiments of Dr Wollaston, we learn that the concretions which sometimes form in the prostate gland have likewise phosphate of lime for their basis.

6. Concretions in the prostate.

7. The extremities of the muscles and the larger blood vessels sometimes harden, and assume the appearance of bone. It is believed that this change is a real ossification, or that these bodies are converted into real bone. I do not know whether any such ossifications have been analysed.

7. Ossifications.

## II. INTESTINAL CONCRETIONS.

CONCRETIONS of very considerable size are sometimes found lodged in the stomach and intestines; sel-

History.

\* Phil. Mag. xlii. 187.

not so easily separated as those of the preceding species\*.

3. *Phosphate of ammonia-and-magnesia*.—This species is the most common of the intestinal concretions. Its colour is grey or brown, and it is composed of crystals diverging like rays from a centre. It has some resemblance to calcareous spar. It contains abundance of animal matter. This species occurs frequently in the intestines of herbivorous animals, as the horse, the elephant, &c.

4. *Biliary*.—This is a species of concretion found frequently in the intestines of oxen, and likewise in their gall-bladder, and employed by painters as an orange yellow pigment. Its colour is reddish brown. It is not composed of layers, but is merely a coagulated mass, and appears to be but little different from the resinous matter of bile. When heated it melts. It dissolves readily in alkalies. Alcohol dissolves it partially, and acquires a very bitter taste†.

5. *Resinous*.—To this species belong many of the oriental bezoards, formerly so celebrated, obtained from the intestines of animals with which we are unacquainted. They are fusible and combustible, composed of concentric layers, smooth, soft, and finely polished. Fourcroy and Vauquelin have distinguished two varieties: The first of a pale green colour, a slightly bitter taste, almost completely volatile; giving by heat a solid tenacious matter, soluble in alcohol, and separating in crystals as the solution cools. This matter consists partly of bile, partly of resin. The second variety has

\* *Ann. de Mus. d'Hist. nat.* 332.

† *Ibid.* 333.

they yielded the products of wood, and left a quantity of charcoal in the retort, which, when incinerated, gave traces of sulphate of soda, muriate of soda, lime, and silica. Thus it appears that they possessed all the properties of pure woody fibre. They must have been formed in the stomach of the animals, and not in the alimentary canal\*.

### III. BILIARY CALCULI.

HARD bodies sometimes form in the gall-bladder, or in the duct through which the bile passes into the intestinal canal, and stop up the passage altogether. These concretions have got the name of *biliary calculi* or *gall-stones*. They naturally drew the attention of physicians, because it was soon ascertained that they occasioned the disease called *jaundice*. Accordingly they were examined and described by different chemists; and the facts ascertained before 1764 were collected by Haller in the sixth volume of his *Physiology*. Since that period, a treatise has been published on them by Vicq d'Azyr; and several new facts have been discovered by Poulletier de la Sale, Fourcroy, Gren, and Saunders. Thenard has lately subjected them to examination†.

History.

Such of the biliary calculi as have been hitherto examined with attention may be arranged under four classes.

Divisible into four classes.

1. The first kind comprehends those which have a

\* *Mém. d'Arcueil*, ii. 442.

† *Ibid.* i. 59.



Book V.

white colour, and a crystallized, shining, lamellar structure. They consist of adipocire.

2. The second species are polygonal, of a lightish brown colour. Externally they have a coat composed of thin concentric layers, within a milder crystallized or having the appearance of catted honey. They are composed chiefly of adipocire but contain a small portion of brown matter, composed of yellow matter of bile a little altered.

3. The third kind are of a brown colour, and are supposed to be composed of altered yellow matter of bile.

4. The fourth comprehends those gall-stones which do not flame, but gradually waste away at a red heat.

Let us take a view of each of these classes of biliary calculi.

1st Species  
resembles  
spermaceæ.

1. The first species of biliary calculi was pointed out for the first time by Haller in a dissertation published in 1749. Walther afterwards added several new facts; and at last it was accurately described by Vicq d'Azyr. It is almost always of an oval form, sometimes as large as a pigeon's egg, but commonly about the size of a sparrow's; and for the most part only one calculus (when of this species) is found in a gall-bladder at a time. It has a white colour; when broken, presents crystalline plates or striz, brilliant and white like mica, and having a soft greasy texture. Sometimes its colour is yellow or greenish; and it constantly a nucleus of inspissated bile\*. Its spe-

\* Pourcroy, *Ann. de Chim.* iii. 249.



gravity is inferior to that of water: Gren found the specific gravity of one 0.803\*.

When exposed to a heat considerably greater than that of boiling water, this crystallized calculus softens and melts, and crystallizes again when the temperature is lowered†. It is altogether insoluble in water; but not alcohol dissolves it with facility. Alcohol, of the temperature of 167°, dissolves  $\frac{1}{10}$  of its weight of this substance; but alcohol, at the temperature of 60°, scarcely dissolves any of it‡. As the alcohol cools, the matter is deposited in brilliant plates resembling talc or boracic acid§. It is soluble in oil of turpentine||. When melted it has the appearance of oil, and exhales the odour of melted wax: when suddenly heated it evaporates altogether in a thick smoke. It is soluble in pure alkalies, and the solution has all the properties of a soap. Nitric acid also dissolves it; but it is precipitated altered by water¶. Indeed the greatest part separates as the liquid cools, and swims on the surface like drops of oil, and seems by the action of the acid to be brought nearly to the state of a resin\*\*. Fourcroy, who first examined this peculiar matter of biliary calculi, has given it the name of *adipocire*, from its resemblance both to fat and to wax.

2. The second kind of biliary calculi is of a polygonal shape, and a number of them almost always exist in the gall-bladder together. To this, probably, they owe their peculiar form. Most commonly they have

2d Species  
nearly similar.

\* *Ann. de Chim.* v. 136.

† *Ibid.* ii. 180.

‡ *Fourcroy, Ibid.* iii. 24

† *Ibid.* ii. 123.

§ *Gren, Ibid.* v. 187.

|| *Nicholson's Jour.* iv. 138.

Book V.

three blunt angles, and have some resemblance to two low tetrahedons, applied base to base, with their edges and angles rounded off. They vary considerably in their specific gravity. A specimen seemingly belonging to this species, examined by Dr Bostock, was of the specific gravity 0.900\*. The mean specific gravity of six which I analysed was 1.061, and they all sunk in water. Their outer surface is smooth, and has a soft feel. When broken they exhibit a thin outer crust, composed of concentric layers, alternately crystallized in small rays inclining towards the centre. The nucleus, in all the specimens which I have examined, had the appearance of granulated honey.

These calculi, in their composition, differ but little from the last species, since they consist almost entirely of adipocire. In six gall-stones which I analysed, the matter amounted to at least  $\frac{1}{2}$ ths of the whole. The residue was a reddish brown substance, insoluble in alcohol. Nitric acid dissolved it readily, and formed a pink-coloured liquid, from which ammonia threw down no precipitate. Pure potash ley dissolved most of it readily when assisted by heat. From the solution, mariatic acid threw down a dark green matter, which had a bitter taste, dissolved in alcohol, melted when heated, and exhibited most of the properties of the resin of bile. The residue, insoluble in potash, was in grey flakes, and resembled albumen in such of its properties as could be traced. But as it never exceeded  $\frac{1}{4}$ th of a grain, it was not possible to ascertain its nature with precision.

---

\* Bostock, Nicholson's *Jour.* iv. 136.

3. I have never had an opportunity of seeing any gall-stones from the human species belonging to the third kind, or composed entirely of altered yellow matter. But in the gall-stones examined by Thenard several were of this kind.

Chap. II.

3d. Of altered yellow matter.

4. Concerning the fourth species of gall stone very little is known with accuracy. Dr Saunders tells us that he has met with some gall-stones insoluble both in alcohol and oil of turpentine; some of which do not flame, but become red, and consume to an ash like a charcoal\*. Haller quotes several examples of similar calculi†. Probably they do not differ from the third kind.

5. The gall stones of oxen are always of a yellow colour, and consist of the yellow matter of bile mixed with minute traces of bile which may be separated by water. They are tasteless, when thus washed, and insoluble in water and alcohol. They are used by painters, though their colour is not permanent, but soon changes to a brown‡.

#### IV. URINARY CALCULI.

It is well known that concretions not unfrequently form in the bladder, or the other urinary organs, and occasion one of the most dismal diseases to which the human species is liable.

These concretions were distinguished by the name of *calculi*, from a supposition that they are of a stony na-

History.

\* On the Liver, p. 112.

† *Physiol.* vi. 567.

‡ Thenard, *Mém. d'Arcueil*, i. 59.



Drs Whytt and Alston pointed out alkalies as solvents of calculi. It was an attempt to discover a more perfect solvent that induced Dr Black to make those experiments which terminated in the discovery of the nature of the alkaline carbonates.

Such was the state of the chemical analysis of calculi, when in 1776, Scheele published a dissertation on the subject in the Stockholm Transactions; which was succeeded by some remarks of Mr Bergman. These illustrious chemists completely removed the uncertainty which had hitherto hung over the subject, and ascertained the nature of the calculi which they examined.

Since that time considerable additional light has been thrown upon the nature of these concretions by the labours of Austin, Walther, Brugnatelli, Pearson, &c. But the most important additions to our knowledge of calculi were made by Dr Wollaston. That ingenious chemist distinguished them into species, and ascertained the composition of each, pointing out several new constituents which had not been suspected before\*. The dissertation on calculi by Fourcroy and Vauquelin is no less important. Many of their results indeed had been anticipated by Wollaston: But they analysed about 500 calculi with precision; a number sufficient to enable them to make a more exact arrangement of them than could be obtained, till the frequency of the occurrence of every ingredient was known. They detected also some substances in calculi which had not been observed in them before. A valuable dissertation on the subject has lately been published by Mr Brande. He

---

\* *Phil. Trans.* 1797.



## Book V.

examined 150 calculi in the rectified some mistakes of several new facts\*.

## Description.

Urinary calculi are usual sometimes they are polyge of mulberries; and in tha by the epithet *mulberry*. times they are very small, goose-egg, or even larger. is a deep brown resembling cases they are white, and of a dark grey, and hard. often intermixed, and occu sity. Their surface in marble; in others, rough a are covered with semitrans cific gravity varies from 1

## Component parts.

The substances hitherto are the following:

1. Uric acid
2. Phosphan
3. Phosphan
4. Oxalate o
5. Muriate c
6. Magnesia
7. Phosphate
8. Silica
9. Urea

\* Phil. Trans. 1808.

† Brugnatelli found also phospho culi.—See *Ann. de Chim.* xxxii. 183.

## 10. Cistic oxide

Chap. II.

## 11. Mucus

1. Uric acid was first discovered in calculi by Scheele. 1. Uric acid.  
 The greater number of these concretions hitherto analysed consisted of it. All those analysed by Scheele were composed of it entirely. Of 900 calculi analysed by Dr Pearson, scarcely one was found which did not contain a considerable quantity of it, and the greater number manifestly were formed chiefly of it. Fourcroy and Vauquelin found it also in the greater number of the 500 calculi which they analysed. Of 150 examined by Brande only 16 were composed entirely of this acid; but almost the whole of them contained this acid.

The presence of this acid may be easily ascertained by the following properties: The calculi formed of it are brown, polished, and resemble wood. A solution of potash or soda dissolves it readily, and it is precipitated by the weakest acids. The precipitate is soluble in nitric acid; the solution is of a pink colour, and tinges the skin red.

2. Phosphate of lime was observed in calculi by Bergman; afterwards it was found in abundance by Pearson, and more lately by Fourcroy and Vauquelin. Dr Wollaston was the first who observed calculi composed of it entirely. The calculi which he examined were brown, and so smooth externally as to appear polished. They were composed of laminae easily separable into concentric crusts. In the calculi observed by Fourcroy and Vauquelin, the phosphate of lime was white, without lustre, friable, stained the hands, paper, and cloth. It had very much the appearance of chalk, broke under the forceps, was insipid and insoluble in water. It is soluble in nitric, muriatic, and acetic acids, and is

2. Phosphate of lime.

of their characters was known till they attracted the attention of that chemist. In all the calculi which he examined, the oxalate was mixed with phosphate of lime, and usually also with uric acid; but Fourcroy and Vauquelin found several in which it was united only to animal matter. It commonly forms a very hard calculus, of a dark green colour, difficult to saw asunder, admitting a polish like ivory, exhaling, when sawed, an odour like that of semen. Insoluble and indecomposable by alkalies; soluble in very diluted nitric acid, but slowly and with difficulty. It may be decomposed by the carbonates of potash and soda. When burnt, it leaves behind a quantity of pure lime, amounting to one-third of its weight, which may be easily recognised by its properties\*.

5. Muriate of ammonia was first detected in calculi by Brande. Fourcroy and Vauquelin had announced the existence of urate of ammonia in calculi. They founded their opinion chiefly on the easy solubility of the supposed urate in alkaline leys, and the smell of ammonia given out during the solution. Brande found that if such calculi were treated with water, a portion was dissolved, and the residue consisted of pure uric acid. The matter dissolved was partly urea and partly muriate of ammonia. To the first of these bodies he ascribed the easy solubility of the calculus, and to the second the smell of ammonia which it gave out during its solution. From his experiments it does not appear that any such salt as urate of ammonia is present in calculi†.

5. Muriate  
of ammo-  
nia.

\* Fourcroy, *Ann. de Chim.* xxxii. 220.

† *Phil. Mag.* xxxii. 171.



Phosphate of lime ....	17.33
Uric acid .....	75.34
Animal matter .....	6.33
Silica .....	1.00
	<hr/>
	100.00*

Chap. II.

Silica was found also in an excessive proportion in the calculus analysed by Alemani, the result of which has been stated above.

9. Urea was suspected to exist in calculi by Fourcroy and Vauquelin, but was first detected by Mr Brande. He obtained it by digesting the calculi supposed to contain it in water or alcohol, and evaporating the solution. The proportion of it seems sometimes to be great. In one instance Mr Brande found 86 per cent. of animal matter, the greatest part of which no doubt was urea †.

9. Urea.

10. The substance called cistic oxide was discovered, and its nature ascertained, by Dr Wollaston. A small calculus, passed from the bladder of a man, was entirely composed of it. It was white, dense, brittle, and had pretty much the appearance of magnesian lime-stone. The characters of this new and peculiar animal substance, as ascertained by Dr Wollaston, are the following: 1. It dissolves and combines equally with acids and alkalies, and crystallizes with both. 2. It is precipitated from nitric acid by alcohol. 3. It does not become red when treated with nitric acid. 4. It produces no change on vegetable blues. 5. It is insoluble in water, alcohol, and ether. 6. When distilled it

10. Cistic oxide.

\* Gehlen's Jour. Second Series. ii. 265. † Phil. Mag. lxxx. 171.



GENUS II. *Calculi composed of two ingredients.*

- Sp. 1. Uric acid and the phosphates in layers.
- Sp. 2. Ditto mixed together.
- Sp. 3. Urate of ammonia and the phosphates in layers.
- Sp. 4. Ditto mixed together.
- Sp. 5. The phosphates mixed or in layers.
- Sp. 6. Oxalate of lime and uric acid in layers.
- Sp. 7. Oxalate of lime and the phosphates in layers.

GENUS III. *Calculi containing more than three ingredients.*

- Sp. 1. Uric acid, the phosphates, and oxalate of lime.
- Sp. 2. Uric acid, urate of ammonia, the phosphates, silica.

Let us take a view of each of these species.

Sp. 1. *Uric acid.* Colour that of wood, various shades of yellow or red. Texture laminar and radiated, compact and fine. Specific gravity from 1.5 to 1.786; sometimes so low as 1.276. Surface usually smooth and polished. Completely soluble in fixed alkaline leys, without emitting any odour of ammonia. This species is the most common. One fourth of the 600 calculi examined by Fourcroy and Vauquelin belonged to it.

Description  
of the spe-  
cies.

Sp. 2. *Urate of ammonia.* Colour brownish white. Texture laminar, laminæ easily separated from each other. Specific gravity from 1.225 to 1.720. Surface often crystallized. Soluble in hot water, especially when reduced to powder. Soluble in fixed alkalis, \*

but its nucleus, instead of uric acid, is composed of urate of ammonia. It is not very common, and the calculi belonging to it are smaller than those of the fourth species.

Sp. 7. *Urate of ammonia and the phosphates mixed.* This species resembles the fifth, but may be distinguished by a colour less yellow, and by the ammonia emitted when the calculi are treated with potash. The calculi belonging to it are small and rather uncommon.

Sp. 8. *The two phosphates mixed or in layers.* Colour white like chalk. Texture laminar; friable, easily separated, and staining the surface of other bodies like chalk. Often mixed with thin layers of phosphate of magnesia-and-ammonia, sparry, and semitransparent. Specific gravity from 1.138 to 1.471. Soluble in acids, insoluble in alkalis. About  $\frac{1}{11}$ th of the calculi examined by Fourcroy and Vauquelin belonged to this species.

Sp. 9. *Oxalate of lime and uric acid in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a layer, more or less thick, of uric acid; or they consist of a small calculus of the third species covered with a layer belonging to the first species. They are easily distinguished when sawn in two. About  $\frac{1}{10}$ th of the 600 calculi analysed by Fourcroy and Vauquelin belonged to this species.

Sp. 10. *Oxalate of lime and the phosphates in layers.* The calculi belonging to this species have a nucleus of oxalate of lime covered with a coat of the phosphates. Externally, therefore, they are the same with the fourth and eighth species; while the internal nucleus belongs to the third species. They are easily distinguished therefore when sawn in two. The calculi of this spe-

3. *Mulberry calculi.* Composed of oxalate of lime or of oxalate and phosphate of lime. In the state of powder they are slowly dissolved by muriatic acid. The residuum is uric acid.

4. *Bone earth calculi.* These, as the name implies, are composed chiefly of phosphate of lime. They are soluble in muriatic acid.

From the observations and experiments of Mr Brande, it appears that the calculi formed in the kidneys, almost always consist of uric acid and animal matter. Sometimes, but very rarely, they consist of oxalate of lime; and when calculi remain in the kidney a considerable time after they have been formed, their external coat consists sometimes of the triple phosphate of magnesia and phosphate of lime\*.

Of 150 calculi found in the bladder, and analysed by Mr Brande, the following was the composition:

16	Composed of uric acid
45	..... uric acid, with a small relative proportion of the phosphates
66	..... the phosphates with a small proportion of uric acid
12	..... the phosphates entirely
5	..... uric acid with the phosphates and nuclei of oxalate of lime
6	..... chiefly oxalate of lime.

150†

From the preceding account of the different urinary calculi, it appears that most of their component parts

\* *Phil. Mag.* xxxii. 167.

† *Ibid.* xxxii. 171.



therefore pass over the numerous lithontriptics\* which have been recommended in all ages, and satisfy myself with giving an account of the experiments made by Fourcroy and Vauquelin to dissolve stones by injections through the urethra, made after their analysis of the urinary calculi.

The component parts of urinary calculi, as far as solvents are concerned, may be reduced under three heads;

1. Uric acid and urate of ammonia
2. The phosphates
3. Oxalate of lime.

Solvents.

1. A solution of pure potash and soda, so weak that it may be kept in the mouth, and even swallowed without pain, soon dissolves calculi composed of uric acid, or urate of ammonia, provided they be kept plunged in it.

2. The phosphates are very quickly dissolved by nitric or muriatic acid, so weak that it may be swallowed without inconvenience, and possessed of no greater acridness than urine itself.

3. Oxalate of lime is much more difficult of solution than the preceding substances. Calculi composed of it are slowly dissolved by nitric acid, or by carbonate of potash or soda, weak enough not to irritate the bladder: but the action of these substances is slow, and scarcely complete.

These solvents injected into the bladder repeatedly, and retained in it as long as the patient can bear their action without inconvenience, ought to act upon the

How applied.

\* There is no room to believe that any of these medicines hitherto proposed, whether alkalics or acids, have any effect as solvents of calculi.



Book V.

stone, and gradually dissolve it. The difficulty, however, is to determine the composition of the calculus to be acted upon, in order to know which of the solvents to employ. But as no method of deciding this point with certainty is at present known, we must try some one of the solvents for once or twice, and examine it after it has been thrown out of the bladder. Let us begin, for instance, with injecting a weak solution of potash; and after it has remained in the bladder half an hour, or longer if the patient can bear it, let the liquid, as soon as passed, be filtered and mixed with a little muriatic acid; if any uric acid has been dissolved, a white solution will make its appearance. This precipitate is a proof that the calculus is composed of uric acid. If it does not appear, after persevering in the alkaline solution for some days, then there is reason to expect the presence of the phosphates; of course a weak muriatic acid solution should be injected. After this solution is emitted, let it be mixed with ammonia, and the phosphate of lime will precipitate, if the calculus be composed of it. If neither of these solutions take up any thing, and if the symptoms are not alleviated, we must have recourse to the action of nitric acid, on the supposition that the calculus is composed of oxalate of lime. These different solutions must be persisted in, and varied occasionally as they lose their efficacy, in order to dissolve the different coats of the calculus. Such are the methods pointed out by Fourcroy and Vauquelin. It is scarcely necessary to observe, that the bladder should be evacuated of urine previous to the injections, and that the injections should be previously heated to the temperature of the body.

## Chap. II.

Calculi of  
inferior ani-  
mals.

THE CALCULI found in the bladder of the inferior animals have been examined by different chemists, especially by Fourcroy and Vauquelin, and by Dr Pearson and Mr Brande. As far as experiment has hitherto gone, they consist chiefly of the three following species.

1. *Carbonate of lime.* These calculi have a white colour, are opaque, and are easily recognized by the action of acids. They occur most frequently in the bladder of the graminivorous animals, and seem to have been first detected by Fourcroy and Vauquelin. The lime is cemented by an animal matter. Calculi belonging to this species have been found in the bladder of the horse \*, the sow †, the rabbit ‡, the ox §.

2. *Earthy phosphate.* These calculi belong chiefly to the carnivorous animals, and seem first to have been examined by Dr Pearson. They consist sometimes of phosphate of lime and animal matter, sometimes of a mixture of phosphate of lime and phosphate of ammonia-and-magnesia and animal matter. They have been found in the bladder of the dog §, the hog ||, the rat ¶, and the cat ¶: And a calculus from a horse, examined by Dr Pearson, was obviously composed of the two phosphates.

3. *Oxalate of lime.* Calculi composed of this substance have been recently detected by Fourcroy and Vauquelin from the bladder of the dog and the rat \*\*.

---

\* Pearson.      † Brugnatelli and Fourcroy.      ‡ Fourcroy.  
§ Pearson.      || Bartholdi.      ¶ Fourcroy and Vauquelin.  
\*\* *Ann. de Mus. d'Hist. Nat.* iv. 338.

## Book V.

The following table exhibits a view of the constituents of the calculi of different animals analysed by Mr Brande :

	Horse *.			Sheep			Dog.			Ung.		
Phosphate of lime	76	45	60	72	64	85						
Carbonate of lime	22	10	40	20		20				90	40	
Phosph. of mag. } and ammonia }		28				30						
Animal matter		15		8	6				10	10		
Loss	2	2										
	100	100	100	100	100	100	100	100	100	100	100	100

Several calculi from the bladder of the ox, likewise examined by Mr Brande, were composed of carbonate of lime and animal matter †.

Thus it appears that the calculi of carnivorous animals resemble the human in their composition, excepting that uric acid has never been detected in them.

## V. GOUTY CONCRETIONS.

It is well known that concretions occasionally make their appearance in joints long subject to gout. These concretions, from their colour and softness, have received the name of *chalk stones*. They are usually small,

Chalk  
stones.

\* The first calculus in the table was from the kidney, all the rest were from the bladder.

† *Phil. Mag.* xxxii. 175.



though they have been observed of the size of an egg \*. It had long been the opinion of physicians that these concretions were similar to the urinary calculi. Of course, after the discovery of uric acid by Scheele, it was usual to consider the gouty chalk stones as collections of that acid. They were subjected to a chemical analysis by Dr Wollaston in 1797, who found them composed of uric acid and soda.

Chap. II.

Consist of  
urate of so-  
da.

Gouty concretions are soft and friable. Cold water has little effect upon them; but boiling water dissolves a small portion. If an acid be added to this solution, small crystals of uric acid are deposited on the sides of the vessel.

These concretions are completely soluble in potash when the action of the alkaline solution is assisted by heat.

When treated with diluted sulphuric or with muriatic acid, the soda is separated; but the uric acid remains, and may be separated by filtration. The liquid, when evaporated, yields crystals of sulphate or muriate of soda, according to the acid employed. The residuum possesses all the characters of uric acid. When distilled it yields ammonia, prussic acid, and the acid sublimate of Scheele. When dissolved in a little nitric acid, it tinges the skin of a rose colour, and when evaporated leaves a rose-coloured deliquescent residuum. It is soluble in potash, and may be precipitated by any acid, and by ammonia; first in the state of a jelly, and then breaking down into a white powder.

\* Severinus.



given. It will be worth while, however, to state the observations that have been made.

Chap. II.

# I. Pus.

The liquid called *pus* is secreted from the surface of an inflamed part, and usually moderates and terminates the inflammation. It assumes different appearances according to the state of the sore. When it indicates a healing sore, it is called *healthy* or *good-conditioned* pus. This liquid possesses the following properties :

It is of a yellowish-white colour, and of the consistence of cream. Its taste is insipid, and it has no smell when cold. Before the microscope it exhibits the appearance of white globules swimming in a transparent fluid\*.

Properties  
of healthy  
pus.

It produces no change on vegetable blues†. When exposed to a moderate heat it gradually dries, and assumes the appearance of horn. When exposed to destructive distillation, Bergman obtained first about one-fourth of the pus in the state of insipid water. On increasing the fire, a liquid came over, containing abundance of ammonia, and accompanied by gaseous bodies, which were not examined. Some concrete carbonate of ammonia sublimed, accompanied by empyreumatic oil. A light brilliant coal remained of difficult incineration. The ashes gave traces of iron‡.

When pus is left exposed to the air, it gradually becomes acid, according to Hildebrandt; and Haller af-

\* Home on *Ulcers*.

† Cruickshanks.

‡ Gren's *Handbuch*, ii. 426.

Such are the properties of healthy pus hitherto observed by chemists. They indicate a considerable analogy with albumen. Various observations have been made to enable physicians to distinguish pus from the mucus of the internal cavities, especially of the lungs. In cases of copious expectoration, it is sometimes of consequence to know whether the matter thrown out of the lungs is pus or mucus. Mr Charles Darwin made a set of experiments on the subject, and pointed out three criteria which distinguished pus. 1. Sulphuric acid dissolves it. When the solution is diluted the pus precipitates; but mucus treated in the same manner swims. But this distinction depends upon the quantity of water added, and is therefore ambiguous. 2. Pus is diffusible through diluted sulphuric acid, through water, and through brine; but mucus is not. 3. Alkaline leys dissolve pus; water precipitates pus thus dissolved, but not mucus. How far these two last distinctions can be trusted, is rather doubtful. Grasmeyer has proposed the following method, which he considers as complete. Triturate the substance to be tried with an equal quantity of warm water; then add to it an equal portion of a saturated solution of carbonate of potash, and set the mixture aside. If it contains pus, a transparent jelly subsides in a few hours; but this does not happen if only mucus be present\*.

2. When the ulcer is ill-conditioned, the pus secreted in it possesses different properties. It has usually a fetid smell, is much thinner, and to a certain degree acrid.

\* *Grœn's Handbuch*, ii. 433.

Crawford found that the odour of this matter was completely destroyed by oxymuriatic acid; and therefore recommends it as a proper substance for washing cancerous ulcers.

4. Besides the species mentioned above, there are many others which we know from their effects to be peculiar, though we cannot find any chemical distinctions between them sufficiently well marked. But that they are specifically different cannot be doubted, if we consider that every one of them produces a disease peculiar to itself. The matter of small pox, of venereal ulcers, of cow-pox, &c. may be mentioned as instances.

## II. LIQUOR OF DROPSY.

The liquor which fills the cavities of the body in dropsy has a yellowish green colour, and is sometimes turbid, sometimes nearly transparent. A few experiments on a colourless liquor extracted from a dropsical patient have been published by Wurzer: from which it appears to have contained albumen, mucus, sulphureted hydrogen, phosphate of lime, and muriate of soda, and soda\*. To Dr Bostock we are indebted for an examination of the colourless liquid obtained by puncturing a tumor in the spine, formed in the disease called *spina bifida*. It was slightly opaque, and did not alter vegetable blues; heat increased its opacity, but did not coagulate it. Its constituents were found to be as follows:

---

\* Gehler's *Jour.* v. 663.

Book V.

Water .....	97·8	
Muriate of soda ...	1·0	
Albumen .....	0·5	
Mucus .....	0·5	} proportions conjectural
Gelatine .....	0·2	
Lime, a trace		

---

 100·0\*

## III. LIQUOR OF BLISTERS.

THE liquid which makes its appearance when the epidermis is raised into blisters is perfectly transparent and liquid. When the blisters are artificial, it is usually yellow, and has the odour of the blistering plaster. From the experiments of Margueron, we learn that it is composed of the same constituents as the serum of the blood. From 200 parts of this liquid he obtained,

Constituents.

36 albumen
4 muriate of soda
2 carbonate of soda
2 phosphate of lime
156 water
<hr/>
200†

Thus I have given an account of all those secretions which have been attentively examined by chemists.

\* Nicholson's Jour. xiv. 145.

† Ann. de Chim. xiv. 225.



The remainder have been hitherto neglected; partly Chap. II.  
owing to the difficulty of procuring them, and partly  
on account of the multiplicity of other objects which  
occupied the attention of chemical philosophers. It re-  
mains for us now to examine by what processes these  
different secretions are formed, how the constant waste  
of living bodies is repaired, and how the organs them-  
selves are nourished and preserved. This shall form  
the subject of the following Chapter.

## CHAP. III.

## OF THE FUNCTIONS OF ANIMALS.

THE intention of the two last Chapters was to exhibit a view of the different substances which enter into the composition of animals, as far as the present limited state of our knowledge puts it in our power. But were our inquiries concerning animals confined to the mere ingredients of which their bodies are composed, even supposing the analysis as complete as possible, our knowledge of the nature and properties of animals would be imperfect indeed.

How are these substances arranged? How are they produced? What purposes do they serve? What are the distinguishing properties of animals, and the laws by which they are regulated?

Animals resemble vegetables.

Animals resemble vegetables in the complexity of their structure. Like them, they are machines nicely adapted for particular purposes, constituting one whole, and continually performing an infinite number of the most delicate processes. But neither an account of the structure of animals, nor of the properties which distinguish them from other beings, will be expected here: These topics belong entirely to the anatomist and physiologist. I mean in the present Chapter to take a view

of those processes only that are concerned in the *production* of animal substances, which alone properly belong to Chemistry. The other functions are regulated by laws of a very different nature, which have no resemblance or analogy to the laws of Chemistry or Mechanics.

---

### SECT. I.

#### OF DIGESTION.

**E**VERY body knows that animals require food, and that they die sooner or later if food be withheld from them. There is indeed a very great difference in the quantity of food which animals require, and in the time which they can pass without it. In general, those animals which are most active require most, and those which are most indolent require least food. The cause of this is pretty obvious; the bodies of animals do not remain stationary, they are constantly wasting; and the waste is proportional to the activity of the animal. Hence the body must receive, from time to time, new supplies, in place of what has been carried off. The use of food answers this purpose.

Food necessary.

2. We are much better acquainted with the food of animals than of vegetables. It consists of almost all the animal and vegetable substances which have been treated of in this and the preceding Book: for there are but very few of them which some animal or other does not use as food. Man uses as food chiefly the muscles of animals, the seed of certain grasses, and a variety of

Its nature,

## Book V.

vegetable fruits. Almost particular substances on which. Some of them feed on animal. Man has a greater range ; number of substances. This would be useless ; as we want accuracy what it is which is more nourishing than another.

Many substances do not and not a few, instead of nourishment last are called *poisons*. So the decomposing the animal body is not so well understood.

Converted  
into chyme  
in the sto-  
mach.

3. The food is introduced into the mouth, and almost all a pulpy consistence. In man this is done in the mouth with the tongue and saliva with which it is there. In animals ground their food in a mill. In man the food has been thus ground in the stomach, where it is subjected to a strong soft fermentation. In different animals : in man it is in a bag of a *bag pipe*. In the horse into a soft pap, which has been when first introduced. The

4. Since chyme possesses the property that the food has undergone in the stomach, and that the ingredients proposed have entered into it, in what manner have these changed?

At first they were ascribed to the action of the stomach. The food



ther triturated in that organ: and being long agitated backwards and forwards in it, was at last reduced to a pulp. But this opinion, upon examination, was found not to be true. The experiments of Stevens, Reaumur, and Spallanzani, demonstrated that the formation of chyme is not owing to trituration; for on inclosing different kinds of food in metallic tubes and balls full of holes, in such a manner as to screen them from the mechanical action of the stomach, they found that these substances, after having remained a sufficient time in the stomach, were converted into chyme, just as if they had not been inclosed in such tubes. Indeed the opinion was untenable, even independent of these decisive experiments, the moment it was perceived that chyme differed entirely from the food which had been taken: that is to say, that if the same food were triturated mechanically out of the body, and reduced to pap of precisely the same consistence with chyme, it would not possess the same properties with chyme; for whenever this fact was known, it could not but be evident that the food had undergone changes in its composition.

The change of food into chyme therefore was ascribed by many to *fermentation*. This opinion is indeed very ancient, and it has had many zealous supporters among the moderns. When the word *fermentation* was applied to the change produced on the food in the stomach, the nature of the process called *fermentation* was altogether unknown. The appearances, indeed, which take place during that process had been described, and the progress and the result of it were known: but no attempt had been made to explain the cause of fermentation, or to trace the changes which take place during its continuance. All that could be meant, then, by

## Chap. III.

This change ascribed to the mechanical action of the stomach.

Ascribed to fermentation.

Book V.

saying that the conversion of stomach is owing to fermenting unknown cause which acts on vegetable substances into putrefaction, acted also on food into chyme, and that precisely the same. According to this opinion attempted to be generated in the stomach, actually produced: for it was the operations which were assigned by physiologists as the cause. Some indeed attempted to show by the putrefactive ferment was inconsiderable, compared to the other opinion.

Our ideas respecting fermentation more precise. It signifies the process which takes place when certain substances are mixed together at a certain temperature, with the consequent production of heat. Therefore the conversion of food into fermentation, it is dependent of the stomach a certain temperature; and that the food is converted into chyme exactly in the same manner as it is converted to the same consistency in the stomach at the same temperature out of the body. In the case; substances are reduced in a short time in the stomach unaltered for weeks in the body. This is the case in the experiments of Stevens and

But without reason.

soon digested in the stomach of the dog. Further, if the conversion of food into chyme were owing to fermentation, it ought to go on equally well in the stomach and œsophagus. Now, it was observed long ago by Boyle and Boyle, that when voracious fish had swallowed animals too large to be contained in the stomach, that not only what was in the stomach was converted into chyme, while what was in the œsophagus remained unchanged; and this has been fully confirmed by subsequent observations.

Chap. III.

Still farther, if the conversion were owing to fermentation, it ought always to take place equally well, provided the temperature be the same, whether the stomach be in a healthy state or not. But it is well known that this is not the case. The formation of chyme depends very much on the state of the stomach. When that organ is diseased, digestion is constantly ill performed. In these cases, indeed, fermentation sometimes appears, and produces flatulence, acid eructations, &c. which are the well-known symptoms of indigestion. These facts, which have been long known, are incompatible with the supposition, that the formation of chyme is owing to fermentation. Accordingly that opinion has been for some time abandoned, by all those anatomists who have taken the trouble to examine the subject.

The formation of chyme, then, is owing to the stomach; and it has been concluded, from the experiments of Stevens, Reaumur, Spallanzani, Scopoli, Brugnatelli, Carimini, &c. that its formation is brought about by the action of a particular liquid secreted by the stomach, and for that reason called *gastric juice*.

Owing to the action of the gastric juice.

That it is owing to the action of a liquid is evident; because, if pieces of food be inclosed in close tubes,



The gastric juice does not continue always of the same nature, even in the same animal; it changes gradually according to circumstances. Graminivorous animals may be brought to live on animal food; and after they have been accustomed to this for some time, their stomachs become incapable of digesting vegetables. On the other hand, those animals which naturally digest nothing but animal food may be brought to digest vegetables.

5. What is the nature of the gastric juice which possesses these singular properties? It is evidently different in different animals; but it is a very difficult task, if not an impossible one, to obtain it in a state of purity. Various attempts have indeed been made by very ingenious philosophers to procure it; but their analysis of it is sufficient to show us that they have never obtained it in a state of purity.

Methods of  
procuring  
it.

The methods which have been used to procure gastric juice are, *first*, to kill the animal whose gastric juice is to be examined after it has fasted for some time. By this method Spallanzani collected 37 spoonfuls from the two first stomachs of a sheep. It was of a green colour, undoubtedly owing to the grass which the animal had eaten. He found also half a spoonful in the stomach of some young crows which he killed before they had left their nest.

Small tubes of metal pierced with holes, and containing a dry sponge, have been swallowed by animals; and when vomited up, the liquid imbibed by the sponge is squeezed out. By this method, Spallanzani collected 481 grains of gastric juice from the stomachs of five crows.

A *third* method consists in exciting vomiting in the



could cause vomiting whenever  
swallowing air, has employed the  
gastric juice.

Spallanzani has observed that  
morning a quantity of liquid, whi  
tric juice; and he has availed him  
it in considerable quantities.

It is almost unnecessary to re  
these different methods are, and  
sion drawn from the examination  
deviate from the truth. It is imp  
juice obtained by any one of the  
pure; because in the stomach it  
mixed with large quantities of sal  
&c. It may be questioned, inde  
tric juice at all can be obtained b  
as the intention of the gastric ju  
food into chyme, in all probabili  
or at least thrown into the stoma  
sent.

Attempt to  
analyse it.

We need not be surprised, the  
accounts concerning its nature, giv  
sophers who have attempted to ex  
late not so much to the gastric in

According to Brugnatelli, the gastric juice of carnivorous animals, as hawks, kites, &c. has an acid and resinous odour, is very bitter, and not at all watery; and is composed of an uncombined acid, a resin, an animal substance, and a small quantity of muriate of soda\*. The gastric juice of herbivorous animals, on the contrary, as goats, sheep, &c. is very watery, a little muddy, has a bitter saltish taste, and contains ammonia, an animal extract, and a pretty large quantity of muriate of soda†. Mr Carminati found the same ingredients; but he supposes that the ammonia had been formed by the putrefaction of a part of their food, and that in reality the gastric juice of these animals is of an acid nature‡.

The accounts which have been given of the gastric juice of man are so various, that it is not worth while to transcribe them. Sometimes it has been found of an acid nature, at other times not. The experiments of Spallanzani are sufficient to show that this acidity is not owing to the gastric juice, but to the food. He never found any acidity in the gastric juice of birds of prey, nor of serpents, frogs, and fishes. Crows gave an acidulous gastric juice only when fed on grain; and he found that the same observation holds with respect to dogs, herbivorous animals, and domestic fowls. Carnivorous birds threw up pieces of shells and coral without alteration; but these substances were sensibly diminished in the stomachs of hens, even when inclosed in perforated tubes. Spallanzani himself swallowed calcareous substances inclosed in tubes; and when he fed on vegetables and fruits, they were sometimes altered

\* Scopoli, Macquer's *Dict.*† *Ibid.*‡ Sennebier's *Observations on Gastric Juice.*

Book. V.

and a little diminished in weight, just as if they had been put into weak vinegar; but when he used *only* animal food, they came out untouched. According to this philosopher, whose experiments have been by far the most numerous, the gastric juice is naturally neither acid nor alkaline. When poured on the carbonate of potash, it causes no effervescence.

Such are the results of the experiments on the juices taken from the stomach of animals. No conclusion can be drawn from them respecting the nature of the gastric juice. But from the experiments which have been made on the digestion of the stomach, especially by Spallanzani, the following facts are established.

Its effect on  
the food.

The gastric juice attacks the surface of bodies, unites to the particles of them, which it carries off, and cannot be separated from them by filtration. It operates with more energy and rapidity the more the food is divided, and its action is increased by a warm temperature. The food is not merely reduced to very minute parts; its taste and smell are quite changed; its sensible properties are destroyed, and it acquires new and very different ones. This juice does not act as a ferment; so far from it, that it is a powerful antiseptic, and even restores flesh already putrefied. There is not the smallest appearance of such a process; indeed, when the juice is renewed frequently, as in the stomach, substances dissolve in it with a rapidity which excludes all idea of fermentation. Only a few air bubbles make their escape, which adhere to the elementary matter, and carry it up to the top, and which are probably extricated by the heat of the solution.

With respect to the substances contained in the stomach, only two facts have been perfectly ascertained.



The first is, that the juice contained in the stomach of oxen, calves, sheep, invariably contains uncombined phosphoric acid, as Macquart and Vauquelin have demonstrated: The second, that the juice contained in the stomach, and even the inner coat of the stomach itself, has the property of coagulating milk and the serum of blood. Dr Young found that seven grains of the inner coat of a calf's stomach, infused in water, gave a liquid which coagulated more than 100 ounces of milk; that is to say, more than 6657 times its own weight; and yet, in all probability, its weight was not much diminished.

Chap. III.  
Substances  
found in  
the sto-  
mach.

What the substance is which possesses this coagulating property, has not yet been ascertained; but it is evidently not very soluble in water: for the inside of a calf's stomach, after being steeped in water for six hours, and then well washed with water, still furnishes a liquor on infusion which coagulates milk\*. And Dr Young found that a piece of the inner coat of the stomach, after being previously washed with water, and then with a diluted solution of carbonate of potash, still afforded a liquid which coagulated milk and serum.

It is evident, from these facts, that this coagulating substance, whatever it is, acts very powerfully; and that it is scarcely possible to separate it completely from the stomach. But we know at present too little of the nature of coagulation to be able to draw any inference from these facts. An almost imperceptible quantity of some substances seems to be sufficient to coagulate milk: For Mr Vaillant mentions, in his Travels in Africa, that

\* Dr Young.



Book V.

a porcelain dish which he procured, and which had lain for some years at the bottom of the sea, possessed, in consequence, the property of coagulating milk when put into it; yet it communicated no taste to the milk, and did not differ in appearance from other cups.

It is probable that the saliva is of service in the conversion of food into chyme as well as the gastric juice. It evidently serves to dilute the food; and probably may be serviceable also by communicating oxygen.

Chyme  
converted  
into chyle  
and excrement.

6. The chyme, thus formed, passes from the stomach into the intestines, where it is subjected to new changes, and at last converted into two very different substances, chyle and excrementitious matter.

Nature of  
chyle.

The *chyle* is a white-coloured liquid, very much resembling milk. It is exceedingly difficult to collect in any considerable quantity, and for that reason it has never been accurately analysed. We know only in general that it resembles milk; containing, like it, a albuminous part capable of being coagulated, a serum, and globules which have a resemblance to cream\*. It contains also different salts; and, according to some, a substance scarcely differing from the sugar of milk. Dr. Charles Smith of New Jersey relates an instance of a dropsy of the abdomen, in which the liquid accumulated appears to have been chyle. The patient, a boy twenty years of age, was tapped twice, and each time between seven and eight quarts of liquid abstracted. Its colour was chalky-white, and resembled milk pretty nearly, both in its taste, smell, and appearance. On standing

---

\* Fordyce on Digestion, p. 121.

a night, it threw up a good cream, though not so much in proportion as cow's milk usually does \*.

7. Concerning the process by which chyle is formed from chyme, scarcely any thing is known. It does not appear that the chyme is precisely the same in all animals; for those which are herbivorous have a greater length of intestine than those which are carnivorous. It is certain that the formation of the chyle is brought about by a chemical change, although we cannot say precisely what that change is, or what the agents are by which it is produced. But that the change is chemical, is evident, because the chyle is entirely different, both in its properties and appearance, from the chyme. The chyme, by the action of the intestines, is separated into two parts, chyle and excrement: the first of which is absorbed by a number of small vessels called *lacteals*; the second is pushed along the intestinal canal, and at last thrown out of the body altogether.

Its formation a chemical process.

After the chyme has been converted into chyle and excrement, although these two substances remain mixed together, it does not appear that they are able to decompose each other; for persons have been known seldom or never to emit any excrementitious matter *per anum* for years. In these, not only the chyle, but the excrementitious matter also, was absorbed by the *lacteals*; and the excrement was afterwards thrown out of the body by other outlets, particularly by the skin: in consequence of which, those persons have constantly that particular odour about them which distinguishes excrement. Now, in these persons it is evident that the

\* *Phil. Mag.* ix. 16.

## Book V.

chyle and excrement, though mixed together, and even absorbed together, did not act on each other; because these persons have been known to enjoy good health for years, which could not have been the case had the chyle been destroyed.

## Use of the bile.

It has been supposed by some that the decomposition of the chyme, and the formation of chyle, is produced by the agency of the bile, which is poured out abundantly, and mixed with the chyme, soon after its entrance into the intestines. If this theory were true, no chyle could be formed whenever any accident prevented the bile from passing into the intestinal canal: but this is obviously not the case; for frequent instances have occurred of persons labouring under jaundice, but the bile ducts being stopped, either by gall-stones or some other cause, so completely, that no bile could pass into the intestines; yet these persons have lived for a considerable time in that state. Consequently digestion, and therefore the formation of chyle, must be possible, independent of bile.

The principal use of the bile seems to be to separate the excrement from the chyle, after both have been formed, and to produce the evacuation of the excrement out of the body. It is probable that these substances would remain mixed together, and that they would perhaps even be partly absorbed together, were it not for the bile, which seems to combine with the excrement, and by this combination to facilitate its separation from the chyle, and thus to prevent its absorption. Fourcroy supposes that the bile, as soon as it is mixed with the contents of the intestinal canal, suffers a decomposition: that its alkali and saline ingredients combine with the chyle, and render it more liquid,



while its albumen and resin combine with the excrementitious matter, and gradually render them less fluid \*. From the late experiments of Berzelius on feces, detailed in the preceding Chapter, it cannot be doubted that the constituents of the bile are to be found in the excrementitious matter: So that the ingenious theory of Fourcroy is so far probable. The bile also stimulates the intestinal canal, and causes it to evacuate its contents sooner than it otherwise would do; for when there is a deficiency of bile the body is constantly constive.

8. The chyle, after it has been absorbed by the lacteals, is carried by them into a pretty large vessel, known by the name of the *thoracic duct*. Into the same vessel likewise is discharged a transparent fluid, conveyed by a set of vessels which arise from all the cavities of the body. These vessels are called *lymphatics*, and the fluid which they convey is called *lymph*. In the thoracic duct, then, the chyle and the lymph are mixed together.

Chyle  
mixes with  
lymph,

Very little is known concerning the nature of the *lymph*, as it is scarcely possible to collect it in any quantity. It is colourless, has some viscosity, and is said to be specifically heavier than water. It is said to be coagulable by heat; if so, it contains albumen; and from its appearance it probably contains gelatine. Its quantity is certainly considerable, for the lymphatics are very numerous.

9. The chyle and lymph being thus mixed together, are conveyed directly into the blood vessels. The ef-

And is con-  
veyed to  
the lungs.

---

\* Fourcroy, T. 48.



Book V.

fect produced by their union in the thoracic duct is not known, but neither the colour nor external properties of the chyle are altered. In man, and many other animals, the thoracic duct enters at the junction of the left subclavian and carotid veins, and the chyle is conveyed directly to the heart, mixed with the blood, which already exists in the blood vessels. From the heart, the blood and chyle thus mixed together are propelled into the lungs, where they undergo farther changes.

Such are the phenomena of digestion, as far as they have been traced. The food is first conveyed to the stomach, where, by means of the gastric juice, it is converted into chyme. The chyme passes into the intestinal canal, where it is subjected to a new process, being gradually decomposed and converted into chyle and excrementitious matter, which, by means of the bile, are separated from each other. The excrementitious matter is evacuated, but the chyle is absorbed by the lacteals, and conveyed to the blood vessels and lungs. Let us now endeavour to trace the changes produced on it by these organs.

---

## SECT. II.

### OF RESPIRATION.

Respiration  
Necessary.

THE absolute necessity of respiration, or of something analogous, is known to every one; and few are ignorant that in man, and hot blooded animals, the or-

gan by which respiration is performed is the lungs: Chap. III.  
Now respiration consists in drawing a certain quantity of air into the lungs, and throwing it out again alternately. Whenever this function is suspended, even for a very short time, the animal dies.

The fluid respired by animals is common atmospheric air; and it has been ascertained by experiment, that no other gaseous body with which we are acquainted can be substituted for it. All the known gases have been tried; but they all prove fatal to the animal which is made to breathe them. Gaseous bodies, as far as respiration is concerned, may be divided into two classes:

1. Unrespirable gases; 2. Respirable gases.

I. The gases belonging to the first class are of such a nature that they cannot be drawn into the lungs of an animal at all; the epiglottis closing spasmodically whenever they are applied to it. To this class belong carbonic acid, and probably all the other acid gases, as has been ascertained by the experiments of Pilatre de Rozier \*. Unrespirable gases. Ammoniacal gas belongs to the same class;

\* *Jour. de Phys.* xviii. 418.—Pilatre de Rozier went into a brewer's tub while full of carbonic acid gas evolved by fermentation. A gentle heat manifested itself in all parts of his body, and occasioned a sensible perspiration. A slight itching sensation constrained him frequently to shut his eyes. When he attempted to breathe, a violent feeling of suffocation prevented him. He sought for the steps to get out; but not finding them readily, the necessity of breathing increased, he became giddy, and felt a tingling sensation in his ears. As soon as his mouth reached the air he breathed freely, but for some time he could not distinguish objects; his face was purple, his limbs weak, and he understood with difficulty what was said to him. But these symptoms soon left him. He repeated the experiment often; and always found, that as long as he continued without breathing, he could speak and move about without inconvenience; but whenever he attempted to breathe, the feeling of suffocation came on.—*Ibid.* p. 421.

## Book V.

Respirable  
gases, of  
four kinds.

1. Suffocate.

2. Kill by  
occasioning  
changes in  
the blood.3. Support  
life imper-  
fectly.4. May be  
breathed  
without in-  
jury.

for the lungs of animals suffocated by it were found by Pilatre not to give a green colour to vegetable blues\*.

II. The gases belonging to the second class may be drawn into the lungs, and thrown out again without any opposition from the respiratory organs; of course the animal is capable of respiring them. They may be divided into four subordinate classes: 1. The first set of gases occasion death immediately, but produce no visible change in the blood. They occasion the animal's death merely by depriving him of air, in the same way as he would be suffocated by being kept under water. The only gases which belong to this class are *hydrogen* and *azotic*.—2. The second set of gases occasion death immediately, but at the same time they produce certain changes in the blood, and therefore kill not merely by depriving the animal of air, but by certain specific properties. The gases belonging to this class are *carbureted hydrogen*, *sulphureted hydrogen*, *carbonic oxide*, and perhaps also *nitrous gas*.—3. The third set of gases may be breathed for some time without destroying the animal, but death ensues at last, provided their action be long enough continued. To this class belong the *nitrous oxide* and *oxygen gas*.—4. The fourth set may be breathed any length of time without injuring the animal. *Air* is the only gas of this body belonging to this class †.

\* *Jour. de Phys.* xxviii. 424.

† See Chaussier's experiments, *Ibid.* lvi. 35.

‡ Perhaps also nitrous gas might have the same effect, if it could be breathed by an animal whose lungs contained no oxygen.

§ For by far the completest account of all the experiments made on the respiration of animals, the reader is referred to De Bore's



It has been long known that an animal can only breathe a certain quantity of air for a limited time; after which it becomes the most deadly poison, and produces suffocation as effectually as the most noxious gas, or a total absence of air. It was suspected long ago that this change is owing to the absorption of a part of the air; and Mayow made a number of very ingenious experiments in order to prove the fact. In 1757 Dr Black, by breathing through lime-water, ascertained that the air, when thrown out of the lungs, contained carbonic acid\*. This discovery was still farther confirmed by Lavoisier in his first dissertation on respiration, published in the Memoirs of the French Academy for 1777. Priestley and Scheele demonstrated that the quantity of oxygen in atmospherical air is diminished by respiration. It was afterwards proved by Lavoisier, and many other philosophers, who confirmed and extended his facts, that no animal can live in air totally destitute of oxygen. Even fish, which do not sensibly respire, die very soon if the water in which they live be deprived of oxygen gas. Frogs, which can suspend their respiration at pleasure, die in about forty minutes, if the water in which they have been confined be covered over with oil †. Insects and worms, as Vauquelin has proved, exhibit precisely the same phenomena. They require air as well as other animals, and die like them if they be deprived of it. They diminish the quantity of oxygen in the air in

Chap. III.

Oxygen necessary in respiration.

---

excellent *Essay on Respiration*. Nor are the clearness, impartiality, and solid judgment of this author inferior to the extent of his information.

\* Black's *Lectures*, ii. 87.

† Carradori, *Ann. de Chim.* xix. 171.



Book V.

which they live, and give out, by respiration, the very same products as other animals. Worms, which are more retentive of life than most other animals, or at least not so much affected by poisonous gases, absorb every particle of the oxygen contained in the air in which they are confined before they die. Mr Vauquelin's experiments were made on the *gryllus viridissima*, the *limax flavus*, and *helix pomatia* \*.

The quantity of air respired differs very much in different animals. Man and hot-blooded animals are under the necessity of breathing constantly; whereas amphibious animals have a certain power over respiration, and can suspend the function altogether for a limited time. Dr Barclay has ascertained that these animals acquire a much greater command over their respiratory organs by habit. Fish do not breathe at all, and consume so little air, that the small portion of it held in solution by the water in which they swim is sufficient for them. It appears that the number of respirations made in a given time differ considerably in different men. Dr Hales reckons them at 20 in a minute. A man on whom Dr Menzies made experiments, breathed only 14 times in a minute. Mr Dery informs us that he makes between 26 and 27 in a minute. I myself make about 19 at an average. The average of all is 20. Now 20 in a minute make 25,200 in 24 hours.

Number of  
respirations.

Quantity of  
air respired.

The quantity of air drawn in and emitted at every respiration must differ considerably with the size of the man and the capacity of his lungs. Dr Menzies found

\* *Ann. de Chim.* xii. 272.

that a man draws in at a medium 40 cubic inches of air at every inspiration. Dr Goodwin has concluded, from his experiments, that, after a complete expiration, the mean quantity of air which remains in the lungs amounts to 109 cubic inches; and Menzies has endeavoured to prove that, after an ordinary expiration, there remains 179. Mr Davy has concluded that his lungs, after a forced expiration, still retain 41 cubic inches of air; after a natural expiration they contain

118 cubic inches

After a natural inspiration 135

After a forced inspiration 254

By a full forced expiration, after a forced inspiration, he threw out ..... 190 cubic inches

After a natural inspiration .. 78.5

After a natural expiration .. 67.5

Messrs Allen and Pepys have calculated, that, in an ordinary inspiration, 16.5 cubic inches of air are drawn into the lungs. In their experiments the average quantity of air thrown out of the lungs in an expiration amounted to 61 cubic inches, but the breathing was much fuller and slower than usual. In one case a forced expiration amounted to 166 cubic inches; in another to 204 cubic inches. From the experiments of the same gentlemen it appears, that the lungs of a stout man about five feet ten inches high after death contain nearly 100 cubic inches of air\*.

Dr Menzies' estimate of an ordinary inspiration seems to approach nearest the average; but Dr Bostock has shown that his estimate of the capacity of the lungs is too low. Perhaps we shall not err very much if

---

\* *Phil. Trans.* 1809.

Book V.

we suppose, with him, that the ordinary quantity of air contained in the lungs is 280 cubic inches; and that 40 inches, or  $\frac{1}{7}$ th of the whole, is drawn in and thrown out at every ordinary respiration. This, supposing 20 respirations in a minute, will make the quantity of air drawn in and thrown out of the lungs every minute amount to 800 inches; to 48,000 inches in the hour; and to 1,152,000 inches in 24 hours, which amounts to rather more than  $52\frac{1}{2}$  lbs avoirdupois. If this estimate is too high, it is probably at least as near the truth as that of Allen and Pepys, which appears as much too low.

Let us now endeavour to trace the changes produced by respiration. These are of two kinds, namely, 1. The changes produced upon the air respired; 2. Changes produced upon the blood exposed to this air. Each of these naturally claims our attention.

Changes  
produced  
on the air  
respired.

1. For our knowledge of the changes produced upon the air by respiration, we are chiefly indebted to Priestley, Cigna, Menzies, Lavoisier and Seguin, Davy, Allen and Pepys. These changes are the following:  
1. Part of the oxygen of the air respired disappears;  
2. Carbonic acid gas is found in its place; 3. It is loaded with water in the state of vapour.

Change of  
bulk.

1. A considerable number of experiments have been made to determine the change of bulk which air undergoes by being respired. According to Davy, air, by a single inspiration and expiration, is diminished from  $\frac{1}{10}$ th to  $\frac{1}{100}$ th part of its bulk\*. In the numerous and accurate experiments made by Allen and Pepys

---

\* Davy's *Researches*, p. 431.



a very large scale, the average diminution was little more than half a *per cent.*, and even this seems to have been owing rather to unavoidable inaccuracy than to real absorption. In the experiments of Berthollet, conducted also with very great care, the diminution varied from 0.69 to 3.70 *per cent.* \* If, with Dr Bostock, we take  $\frac{1}{100}$ th as the average diminution, and 40 inches as the quantity of air drawn into the lungs at each inspiration, then it will follow that half a cubic inch of the air disappears each time we respire. This in a day would amount to 14,400 cubic inches, which is rather more than eight cubic feet.

When air is breathed till the animal can support it no longer, the diminution which it undergoes is variously stated. Mr Davy found it to amount to  $\frac{1}{100}$ th of the whole air †; Lavoisier and Goodwyn to  $\frac{1}{80}$ th ‡; Allen and Pepys to  $\frac{1}{14}$ th §; and Crawford ||, on the other hand, found no diminution at all. These numbers vary so much from each other, and from the estimate from a single respiration, that it is impossible to avoid concluding the diminution to be different at different times. I was induced by a letter from Mr Dalton, in the summer of 1806, to make some experiments on the subject. In some cases I could perceive no diminution at all; in others it was perceptible. It was greatest when the animal was taken out repeatedly during the experiment, or when air was employed which was purer than that of the atmosphere. I am

\* *Mem. d'Arcueil*, ii. 461.

† *Davy's Researches*, p. 435.

‡ Bostock on *Respiration*, p. 87.

§ *Phil. Mag.* xxxii. 254.

|| Crawford on *Heat*, p. 146.



coincidence would dispose us to embrace this result as affording a near approximation to the truth. We may conclude, then, that in a day a man consumes rather more than 25 cubic feet of oxygen. Now, since the oxygen amounts only to about one-fifth of the atmosphere, it follows, that in a day, a man destroys, or renders unfit for supporting combustion and respiration, no less than 125 cubic feet of air. The result obtained by Messrs Allen and Pepys is somewhat less, or about 27.5 cubic inches per minute. And they think that in ordinary respiration the proportion consumed is much smaller.

3. The air which is thrown out of the lungs contains in it a quantity of carbonic acid which did not exist in it previous to its being used for respiration. Dr Menzies conceived that the bulk of this gas is precisely equivalent to that of the oxygen consumed. This also was the result of the experiments of Dr Crawford. Lavoisier, in his experiments on the Guinea pig, found it somewhat less. In his first experiment he found the oxygen consumed, to the carbonic acid formed, as 20 to 16.5; in his second, as 20 to 17.3\*. In his experiments on Seguin, in 1789, the oxygen consumed was to the bulk of carbonic acid formed nearly as 20 to 16.6; but in those that were made afterwards, the proportion of carbonic acid is diminished by nearly one-half. In Mr Davy's experiments, the bulk of carbonic acid formed corresponded very nearly with that of the oxygen consumed†; so that in this respect they coincided

Carbonic acid formed;

\* See the details, *Mem. Par.* 1780, p. 401.; *Ann. de Chim.* v. 261.; and in Bostock on *Respiration*, p. 79.

† Davy's *Researches*, p. 431.

Book V.

with those of Crawford and Menzies. I was informed by Mr Dalton, in the summer of 1806, that he had satisfied himself, by a variety of experiments, that the bulk of carbonic acid gas formed was exactly equal to that of the oxygen gas consumed. On repeating the experiment with that particular view, I found that in some cases this took place very nearly; but upon the whole, the bulk of oxygen which disappeared was somewhat greater than that of the carbonic acid formed; but the difference varied considerably, and kept pace with the diminution of the bulk of air by respiration. Hence I consider it as owing to the abstraction of a part of the air by some other way than respiration. If this abstraction be allowed for, I have no doubt, from my own experiments, that the bulk of the carbonic acid formed by respiration is precisely equal to that of the oxygen which has disappeared. The absolute quantity is difficult to state, as it depends upon a variety of circumstances. I am disposed to consider it, at an average, as approaching to 40,000 cubic inches in 24 hours, though probably somewhat under that quantity. Now, the quantity of carbonic acid contains little less than three quarters of a pound avoirdupois of carbon. Messrs Allen and Pepys found the carbonic acid formed exactly equal in bulk to the oxygen which had disappeared. It amounted in their experiments to about  $27\frac{1}{2}$  cubic inches per minute, or 39,534 cubic inches in 24 hours, a quantity which contains above 11 ounces troy of solid carbon. Air thrown out of the lungs contained in their experiments about 8 per cent. of carbonic acid gas. In Berthollet's experiments, the carbonic acid gas forma-

ed varied from 5.53 to 13.82 *per cent.* But the animal was confined for several hours in the same air \*.

Chap. III.

4. Dr Priestley concluded from his experiments, that not only the oxygen, but the azote also, of the air respired was diminished †. This opinion was still farther confirmed by Davy, who found the consumption of azote to amount to about  $\frac{1}{4}$ th of that of the oxygen ‡. Dr Henderson has lately made experiments with the same result, though the proportion of azote absorbed was rather less §. Upon repeating these experiments, I found likewise a loss of azote; but it was extremely inconstant, sometimes being scarcely perceptible, and at other times considerable. It kept pace with the diminution of the bulk of the air respired, and with the difference between the bulk of the oxygen consumed and the carbonic acid formed. Hence I am disposed to ascribe all of these differences to the same cause. I conceive that a portion of the air respired disappears without undergoing any change, and that this portion occasions the diminution of the azote, and the difference between the bulk of the carbonic acid formed and the oxygen consumed. What comes of this portion of air it is difficult to say; but I think it conceivable that the disappearing of such a portion may be confined to the unnatural circumstances occasioned by the experiment; that the difficulty of throwing out the air from the lungs in these circumstances may be such as to induce absorbents to act, and remove a portion which, in the ordinary situation of the lungs, would have been thrown

Azote.

\* *Mem. d'Arcueil*, ii. 461.

† Priestley, ii. 380.

‡ Davy's *Researches*, p. 433.

§ Nicholson's *Jour.* viii. 44.



vapour actually emitted from the lungs. Supposing 10 inches of air to be drawn in at each inspiration, it was easy to calculate, from Dalton's table, the weight of the vapour which it contained when emitted.

6. In ordinary cases of respiration, the oxygen, which disappears, is just balanced by the carbonic acid formed, so that the bulk of the air continues unaltered: but it appears from the experiments of Messrs Allen and Pepys, that when the same quantity of air is breathed backwards and forwards as long as possible, a greater quantity of oxygen disappears than can be accounted for by the carbonic acid formed. This oxygen is absorbed by the system. It diminishes the bulk of the air respired, and amounts to about  $\frac{1}{12}$ th of the whole air respired at an average.

7. When oxygen gas, nearly pure, is breathed, rather a greater quantity of carbonic acid is given out; for the air expired contains, at an average, above ten *per cent.* of that gas. It appears also from the experiments of Messrs Allen and Pepys, that a portion of the oxygen gas disappears, and then an equal bulk of azotic gas is found in its place. This substitution of azote is greatest at the commencement of the experiment, and diminishes as the respiration continues. It is difficult at present to account for this substitution. The quantity observed, amounting at an average to nearly 80 cubic inches, is too great to be ascribed to an error in the experiment. It can only be fully accounted for when we become acquainted with the composition of azote, which is still unknown; though, from the recent experiments of Davy and Berzelius, there can be no doubt that it is a compound.

Respiration  
of oxygen  
gas;



Nature of the gases.	Gases before experiment.	Ditto after ditto.	Difference.	The fishes have		Azote absorbed, the oxygen being 100.	Carb. acid produced, the oxygen absorbed being 100.	Number of fishes and time.
				Absorbed	Produced			
total oxygen nitrate carbonic acid	175.0 52.1 115.9 7.0	135.1 5.6 95.8 33.7	39.9	46.5 25.1	26.7	43	57	Three tenches during 5 hours, 15 minutes.
total oxygen nitrate carbonic acid	524.0 155.9 347.1 21.0	404.0 44.0 249.5 110.9	119.6	111.9 97.6	89.9	87	80	Seven tenches during 6 hours.
total oxygen nitrate carbonic acid	524.0 151.9 347.1 21.0	453.0 10.5 289.5 133.0	71.0	145.4 57.6	132.0	40	91	Seven tenches during 8 hours.
total oxygen nitrate carbonic acid	483.0 143.7 320.0 19.3	345.5 4.2 294.1 47.2	137.5	139.5 25.9	27.9	19	20	One tench during 17 hours.
total oxygen nitrate carbonic	483.0 143.7 320.0 19.3	408.0 62.6 285.4 60.0	75.0	81.1 34.6	40.7	43	50	Three tenches during 7½ hours.
total oxygen nitrate carbonic acid	483.0 143.7 320.0 19.3	398.6 40.0 246.6 112.0	84.4	103.7 73.4	92.7	71	89	Three tenches during 5 hours.
total oxygen nitrate carbonic acid	483.0 143.7 320.0 19.3	372.5 37.8 252.9 81.8	110.5	105.9 67.1	62.5	63	59	Two tenches during 7 hours*.

\* The numbers in this table indicate cubic centimetres. A cubic centimetre is equal to 0.0610 of a cubic inch.

## Book V.

The quantity of gas obtained from the Seine water, was at an average 0.0275 of its bulk, or not quite  $\frac{1}{36}$  part; the average quantity of oxygen which this gas contained was 0.310.

From these experiments it appears, that the respiration of fishes differs very much from that of other animals. The oxygen is not merely converted into carbonic acid, as happens during the respiration of men and the larger animals; but a portion of it is absorbed and introduced into the system. A portion also of azote is absorbed. The quantity of air consumed by fishes is extremely small, when compared with that consumed by terrestrial animals. This will appear from the following table, in which the bulk of the air consumed, and of the carbonic acid formed in an hour, is stated in cubic inches.

Time.	Oxygen in the air after the experiment.	Number of fish.	Hours the experiment lasted.	Absorption in 1 hour in cubic inches.		Carbonic acid produced in cubic inches.
				Oxygen.	Azote.	
28 Feb.	0.056	3	5 $\frac{1}{4}$	0.0245	0.0106	0.0145
3 March	0.151	7	6	0.0221	0.0102	0.0117
7 March	0.034	7	8 $\frac{1}{2}$			0.0189
11 March	0.017	1	17	0.0679	0.0126	0.0136
28 Feb.	0.178	3	7 $\frac{1}{4}$	0.0298	0.0123	0.0154
24 Feb.	0.141	3	5	0.0575	0.0405	0.0312
20 Feb.	0.130	2	7	0.0635	0.0397	0.0373

From this table, compared with the facts stated in the preceding part of this section, it follows, that in a given time a man consumes 50,000 times as much oxygen gas as a tench. Yet the presence of this principle is equally necessary for the existence of both.

Chap. III.

II. Let us now endeavour to ascertain the changes produced on the blood by respiration. The whole of the blood is propelled from the heart to the lungs, circulates through the vessels of that organ; and during that circulation it is exposed to the influence of the air which the animal is constantly drawing into the lungs. Now, certain changes are produced upon it by this action, which have been partly traced by the experiments of Priestley, Cigna, Fourcroy, Hassenfratz, Beddoes, Watt, and above all by those of Mr. Davy. These changes, as far as we are acquainted with them, are the following: 1. It acquires a florid red colour, and the chyle disappears; 3. It loses a portion of carbon; 4. It emits water.

Changes  
produced  
on the  
blood.

1. It has been long known that the blood which flows in the veins is of a dark reddish purple colour, whereas the arterial blood is of a florid scarlet colour. Lower observed that the colour of the venous blood was converted into that of arterial during its passage through the lungs. No chyle can be distinguished by its white colour in the blood after it has passed through the lungs. The changes, then, which take place upon the appearance of the blood are two: 1. It acquires a florid red colour; 2. The chyle totally disappears. Lower himself knew that the change was produced by the air, and Mayow attempted to prove that it was by absorbing a part of the air. But it was not till Dr Priestley discovered that venous blood acquires a scarlet colour



Book V.

when put in contact with oxygen gas, and arterial blood a dark red colour when put in contact with hydrogen gas; or, which is the same thing, that oxygen gas instantly gives venous blood the colour of arterial; and hydrogen, on the contrary, gives arterial blood the colour of venous blood—it was not till then that philosophers began to attempt any thing like an explanation of the phenomena of respiration.

Action of  
different  
gases on  
blood.

The blood is a fluid of so complex a nature that it is not easy to ascertain the changes produced in it by exposure to different gases out of the body; and even if that could be done, we have no method of proving that the effects of these gaseous bodies upon the coagulated blood are the same as they would be on the blood in its natural state, circulating in the vessels of a living animal. The facts which have been ascertained are the following:

1. Oxygen,

1st, It appears from the experiments of Priestley, Girtanner, and Hassenfratz, that when venous blood is exposed to oxygen gas confined over it, the blood instantly assumes a scarlet colour. Mr Davy could not perceive any sensible diminution of the bulk of the gas.

2. Air,

2d, The same change of colour takes place when blood is exposed to common air. In this case a quantity of carbonic acid gas is formed, and a quantity of oxygen gas, exactly equal to it in bulk, disappears; making allowance for the small quantity of carbonic acid, which we may suppose to be absorbed by the blood itself.

3. Azotic,

3d, Venous blood exposed to the action of azotic gas continues unaltered in colour; neither does any perceptible diminution of the gas ensue.



4th, Venous blood exposed to the action of nitrous gas becomes of a deep purple, and about  $\frac{1}{2}$ th of the gas is absorbed.

Chap. III.

4. Nitrous,

5th, Venous blood exposed to nitrous oxide becomes of a brighter purple, especially on the surface, and a considerable portion of the gas is absorbed.

5. Nitrous oxide,

6th, Venous blood exposed to carbonic acid gas becomes of a brownish red colour, much darker than usual, and the gas is slightly diminished in bulk.

6. Carbonic acid,

7th, Carbureted hydrogen gas gives venous blood a fine red colour, a shade darker than oxygen gas does, as was first observed by Dr Beddoes, and at the same time a small portion of the gas is absorbed. This gas has the property of preventing, or at least greatly retarding, the putrefaction of blood, as was first observed by Mr Watt\*.

7. Carbureted hydrogen.

8th, When arterial blood is put in contact with azotic gas, or carbonic acid gas, it gradually assumes the dark colour of venous blood, as Dr Priestley found†. The same philosopher also observed, that arterial blood acquired the colour of venous blood when placed in *vacuo*‡. Consequently this alteration of colour is owing to some change which takes place in the blood itself, independent of any external agent.

Arterial blood darkened by azotic and carbonic acid gas;

The arterial blood becomes much more rapidly and deeply dark coloured when it is left in contact with hydrogen gas placed above it§. We must suppose therefore that the presence of this gas accelerates and in-

\* Davy's *Researches*, p. 380.

† Priestley, iii. 363.

‡ Ibid. and *Ann. de Chim.* ix. 269.

§ Fourcroy, *III.* vii. 149.

Book V.

By rest,

creases the change, which would have taken place upon the blood without any external agent.

91*b*, If arterial blood be left in contact with oxygen gas, it gradually assumes the same dark colour which it would have acquired *in vacuo*, or in contact with hydrogen; and after this change oxygen can no longer restore its scarlet colour \*. Therefore it is only upon a part of the blood that the oxygen acts; and after this part has undergone the change which occasions the dark colour, the blood loses the power of being affected by oxygen.

And by  
oxymuriatic  
acids.

101*b*, Mr Hassenfratz poured into venous blood a quantity of oxymuriatic acid; the blood was instantly decomposed, and assumed a deep and almost black colour. When he poured common muriatic acid into blood, the colour was not altered †. Now oxymuriatic acid has the property of giving out its oxygen readily; consequently the black colour was owing to the instant combination of a part of the blood with oxygen.

Theory of  
Priestley.

2. Dr Priestley, the first of the modern chemists who turned his attention to respiration, concluded from some of his earliest experiments, that the blood, as it passed through the lungs, gave out phlogiston to the air, which was expired loaded with that substance; and of course that the purpose of respiration was to free the blood of phlogiston. Lavoisier soon after ascertained with more precision the changes which the air undergoes during respiration; and he formed a theory in order to explain that function, assuming as its basis that all the

\* Fourcroy, ix. 268.

† Ibid.

changes on the air inspired are produced in the lungs ; and of course, that all the new substances expired are formed in the lungs. According to him, the blood absorbs no air in the lungs ; but it gives out hydrogen and carbon, which, combining with the oxygen of the air inspired, form water and carbonic acid. This theory was adopted by La Place, Crawford, Gren, and Gintanner, with a small variation. Indeed it does not differ, except in detail, from the original hypothesis of Dr Priestley, that the use of respiration is to rid the blood of phlogiston ; for if we substitute carbon and hydrogen for phlogiston, the two theories precisely agree. Mr Lavoisier attempted not to prove its truth ; he only tried to show that the oxygen absorbed corresponds exactly with the quantity of oxygen contained in the carbonic acid and the water emitted.

Chap. III.

Modified  
by Lavoisier.

A different theory was afterwards proposed by Mr De La Grange. According to this philosopher, the oxygen gas, which disappears, combines with the blood as it passes through the lungs ; and at the instant of this combination there is set free from the blood a quantity of carbonic acid gas and of water, which are thrown out along with the air expired. This theory was adopted and illustrated by Mr Hassenfratz. In the first and second Editions of this Work I embraced this theory, modified a little by the experiments of Davy. A letter which I received from Mr Dalton, in the summer of 1806, combating this theory, and defending that of Crawford, induced me to examine it more narrowly ; and the result of a set of experiments, which I immediately undertook, convinced me that Mr Dalton's objections were well founded. The carbonic acid formed, I consider as exactly equal to the bulk of the oxygen

Theory of  
La Grange.

Crawford's  
theory  
seems correct.



this *must* be formed there, because it does not exist previously. Now, one great end of respiration must undoubtedly be to assist this decomposition of chyle and complete formation of blood.

It follows, from the experiments of Fourcroy formerly enumerated, that fibrin contains more azote, and less carbon, than any of the other ingredients of the blood, and consequently also than any of the ingredients of the chyle. In what manner the chyle, or a part of it, is converted into fibrin, it is impossible to say: we are not sufficiently acquainted with the subject to be able to explain the process. But we can see, at least, that carbon must be abstracted from that part of the chyle which is to be converted into fibrin. Hence, as the process of blood-making advances, there must be a greater and greater redundancy of carbon in the liquid. Unless this redundancy were removed, the process could not go on, and probably the whole would run into putrefaction. We may conclude, then, that one great use of respiration is to abstract this carbon, by forming with it carbonic acid. How this is performed, indeed, it is impossible at present to explain; but the fact is undoubted.

But the abstraction of carbon is not the only advantage gained by respiration: the *temperature* of all animals depends upon it. It has been long known, that those animals which do not breathe have a temperature but very little superior to the medium in which they live. This is the case with fishes and many insects. Man, on the contrary, and quadrupeds which breathe, have a temperature considerably higher than the atmosphere: that of man is 98°. Birds, who breathe in proportion a still greater quantity of air than man, have

Animal  
heat.



Book V.

a temperature equal to  $103^{\circ}$  or  $104^{\circ}$ . It has been proved, that the temperature of all animals is proportional to the quantity of air which they breathe in a given time.

These facts are sufficient to demonstrate that the heat of animals depends upon respiration. But it was not till Dr Black's doctrine of latent heat became known to the world, that any explanation of the cause of the temperature of breathing animals was attempted. The illustrious philosopher, whose discoveries form the basis upon which all the scientific part of chemistry has been reared, saw at once the light which his doctrine of latent heat threw upon this part of physiology, and he applied it very early to explain the temperature of animals.

Dr Black's theory.

According to him, part of the latent heat of the air inspired becomes sensible; and of course the temperature of the lungs, and the blood that passes through them, must be raised; and the blood, thus heated, communicates its heat to the whole body. This opinion was ingenious, but it was liable to an unanswerable objection: for if it were true, the temperature of the body ought to be greatest in the lungs, and to diminish gradually as the distance from the lungs increases; which is not true. The theory, in consequence, was abandoned even by Dr Black himself; at least he made no attempt to support it.

Theory of Crawford.

Dr Crawford, who considered all the changes operated by respiration as taking place in the lungs, accounted for the origin of the animal heat almost precisely in the same manner with Dr Black. According to him, the oxygen gas of the air combines in the lungs with the carbon emitted by the blood. During this combi-

nation, the oxygen gives out a great quantity of caloric, with which it had been combined; and this caloric is not only sufficient to support the temperature of the body, but also to carry off the new-formed water in the state of vapour, and to raise considerably the temperature of the air inspired. According to this philosopher, then, the whole of the caloric which supports the temperature of the body is evolved in the lungs. His theory accordingly was liable to the same objection with Dr Black's; but Dr Crawford obviated it in the following manner: He found that the specific caloric of arterial blood was 1.0300, while that of venous blood was only 0.8928. Hence he concluded, that the instant venous blood is changed into arterial blood, its specific caloric increases; consequently it requires an additional quantity of caloric to keep its temperature as high as it had been while venous blood. This addition is so great, that the whole new caloric evolved is employed: therefore the temperature of the lungs must necessarily remain the same as that of the rest of the body. During the circulation, arterial blood is gradually converted into venous; consequently its specific caloric diminishes, and it must give out heat. This is the reason that the temperature of the extreme parts of the body does not diminish. This theory is extremely ingenious, and accounts for the whole phenomena in a much more satisfactory manner than any other which has been proposed.

## SECT. III.

## OF THE ACTION OF THE KIDNEYS.

Thus we have reason to suppose that chyle and lymph are converted into blood during the circulation: but besides the lungs and arteries, there is another organ, the sole use of which is also to produce some change or other in the blood, which renders it more complex, and more proper for the various purposes to which it is applied. This organ is the KIDNEY.

A very great proportion of blood passes through the kidneys; indeed we have every reason to conclude that the whole of the blood passes through them very frequently. These organs separate the urine from the blood, to be afterwards evacuated without being applied to any purpose useful to the animal.

Action of  
the kidneys  
necessary.

The kidneys are absolutely necessary for the continuance of the life of the animal; for it dies very speedily when they become by disease unfit to perform their functions; therefore the change which they produce in the blood is a change necessary for qualifying it to answer the purposes for which it is intended.

As the urine is immediately excreted, it is evident that the change which the kidneys perform is intended solely for the sake of the blood. It is not merely the abstraction of a quantity of water and of salts, accumulated in the blood, which the kidney performs. A chemical change is certainly produced, either upon the whole blood, or at least on some important part of it.



for there are two substances found in the urine which do not exist in the blood. These two substances are urea and uric acid. They are formed, therefore, in the kidneys; and as they are thrown out, after being formed, without being applied to any useful purpose, they are certainly not formed in the kidneys for their own sake. Some part of the blood, then, must be decomposed in the kidney, and a new substance, or new substances, must be formed; and the urea and uric acid must be formed at the same time, in consequence of the combined action of the affinities which produce the change on the blood; and being useless, they are thrown out together with a quantity of water and salts, which, in all probability, were useful in bringing about the changes which take place in the arteries and in the kidneys, but which are no longer of any service after these changes are brought about.

The changes operated upon the blood in the kidneys are at present altogether unknown; but they must be important. Provided the method of analysing animal substances were so far perfected as to admit of accurate conclusions, considerable light might be thrown upon this subject, by analysing with care a portion of blood from the emulgent vein and artery separately, and ascertaining precisely in what particulars they differ from each other.

Chap. III.

It changes  
the nature  
of the  
blood.



by Bryan Robertson and Rye ; and in Carolina by Lining. The result of all these experiments has been collected by Haller ; but it gives us no precise estimate of the amount of the transpiration, since these philosophers have not distinguished between what is lost by the skin and by the lungs. Lavoisier and Seguin alone have attempted to ascertain the amount of the matter perspired through the skin. A bag composed of varnished silk, and perfectly air-tight, was procured, within which Seguin, who was usually the subject of experiment, was enclosed, and the bag was closed exactly over his head. There was a slit in the bag opposite to his mouth, and the edges of this slit were accurately cemented round the mouth by means of a mixture of turpentine and pitch. Thus every thing emitted by the body was retained in the bag, except what made its escape from the lungs by respiration. By weighing himself in a delicate balance at the commencement of the experiment, and again after he had continued for some time in the bag, the quantity of matter carried off by respiration was ascertained. By weighing himself without this varnished covering, and repeating the operation after the same interval of time had elapsed as in the former experiment, he ascertained the loss of weight occasioned by perspiration and respiration. By subtracting from this sum the loss of weight indicated by the first experiment, he obtained the quantity of matter which made its escape by perspiration in a given time. The following facts were ascertained by these experiments :

1. The maximum of matter perspired in a minute amounted to 26.25 grains troy ; the minimum to nine grains : which gives 17.63 grains at a medium in the

Book V.

minute, or 52·89 ounces in the 24 hours. This quantity differs less than might have been expected from the result of former experiments made by Dodart, Kol, Rye, &c.

2. The quantity perspired is increased by drink, but not by solid food.

3. Perspiration is at its minimum immediately after a repast. It reaches its maximum during digestion<sup>\*</sup>.

The quantity of matter perspired differs very considerably according to circumstances. It has been shown to be greatest in hot weather, and in hot climates, and after great exercise; and its relation to the quantity of urine has been long known. When the matter perspired is great, the quantity of urine is small, and *vice versa*.

Substances  
perspired.

To ascertain the substance thus emitted by perspiration is a difficult task, because it passes off insensibly, and in small quantities at a time. It has, notwithstanding, been ascertained, that water, carbon, and an oily matter, are emitted; and that acetic acid, phosphate of lime, and even urea, are sometimes emitted through the skin<sup>†</sup>.

It has been supposed that the skin has the property of *absorbing moisture* from the air; but this opinion has not been confirmed by experiments, but rather the contrary.

Whether  
the skin  
absorbs  
moisture.

The chief arguments in favour of the absorption of the skin have been drawn from the quantity of moisture discharged by urine being, in some cases, not only greater than the whole drink of the patient, but even

<sup>\*</sup> Fowles, *ib.* 298.

<sup>†</sup> See the preceding Chapter, Sect. 24.

than the whole of his drink and food. But it ought to be remembered that, in diabetes, the disease here alluded to, the weight of the body is continually diminishing, and therefore part of it must be constantly thrown off. Besides, it is scarcely possible in that disease to get an accurate account of the food swallowed by the patients; and in those cases where very accurate accounts have been kept, and where deception was not so much practised, the urine was found not to exceed the quantity of drink\*. In a case of diabetes, related with much accuracy by Dr Gerard, the patient was bathed regularly during the early part of the disease in warm water, and afterwards in cold water: he was weighed before and after bathing, and no sensible difference was ever found in his weight†. Consequently, in that case, the quantity absorbed, if any, must have been very small.

It is well known that thirst is much alleviated by cold bathing. By this plan Captain Bligh kept his men cool and in good health during their very extraordinary voyage across the South Sea. This has been considered as owing to the absorption of water by the skin. But Dr Currie had a patient who was wasting fast for want of nourishment, a tumor in the œsophagus preventing the possibility of taking food, and whose thirst was always alleviated by bathing; yet no sensible increase of weight, but rather the contrary, was perceived after bathing. It does not appear, then, that in either of these cases water was absorbed.

Farther, Seguin has shown that the skin does not ab-

---

\* See Rollo on *Diabetes*.

† *Ibid.* ii. 75.



possible, then, that water, when in the state of vapour, or when dissolved in air, may be absorbed, although water, while in the state of water, may be incapable of pervading the cuticle. The experiments, therefore, which have hitherto been made upon the absorption of the skin, are insufficient to prove that air and vapour cannot pervade the cuticle, provided there be any facts to render the contrary supposition probable.

Now, that there are such facts cannot be denied. I shall not indeed produce the experiment of Van Mons as a fact of that kind, because it is liable to objections, and at best is very indecisive. Having a patient under his care who, from a wound in the throat, was incapable for several days of taking any nourishment, he kept him alive during that time by applying to the skin, in different parts of the body, several times a-day, a sponge dipt in wine or strong soup\*. A fact mentioned by Dr Watson is much more important, and much more decisive. A lad at Newmarket, who had been almost starved in order to bring him down to such a weight as would qualify him for running a horse race, was weighed in the morning of the race day; he was weighed again an hour after, and was found to have gained 30 ounces of weight; yet in the interval he had only taken half a glass of wine. Here absorption must have taken place, either by the skin, or lungs, or both. The difficulties in either case are the same; and whatever renders absorption by one probable, will equally strengthen the probability that absorption takes place by the other†.

---

\* *Phil. Mag.* vi. 95.

† Watson's *Chemical Essays*, iii. 101.—The Abbé Fontana also found



## SECT. V.

## OF ASSIMILATION.

Blood answers two purposes :  
1. Supplies the waste of the system.

WE have now seen the progress of digestion, and the formation of blood, as far at least as we are acquainted with it. But to what purposes is this blood employed, which is formed with so much care, and for the formation of which so great an apparatus has been provided? It answers two purposes. The parts of which the body is composed, bones, muscles, ligaments, membranes, &c. are continually changing. In youth they are increasing in size and strength, and in mature age they are continually acting, and consequently continually liable to waste and decay. They are often exposed to accidents, which render them unfit for performing their various functions; and even when no such accident happens, it seems necessary for the health of the system that they should be every now and then renewed. Materials therefore must be provided for repairing, increasing, or renewing all the various organs of the body; phosphate of lime and gelatine for the bones, fibrin for the mus-

---

that, after walking in moist air for an hour or two, he returned home some ounces heavier than he went out, notwithstanding he had undergone considerable evacuation from a brisk purge purposely taken for the experiment. This increase, indeed, might be partly accounted for by the absorption of moisture by his clothes.

cles, albumen for the cartilages and membranes, &c. Accordingly all these substances are laid up in the blood; and they are drawn from that fluid, as from a storehouse, whenever they are required. The process by which the different ingredients of the blood are made part of the various organs of the body is called ASSIMILATION.

Chap. III.

Assimilation.

Over the nature of assimilation the thickest darkness still hangs: there is no key to explain it, nothing to lead us to the knowledge of the instruments employed. Facts, however, have been accumulated in sufficient numbers to put the existence of the process beyond the reach of doubt. The healing, indeed, of every fractured bone, and every wound of the body, is a proof of its existence, and an instance of its action.

Every organ employed in assimilation has a peculiar office; and it always performs this office whenever it has materials to act upon, even when the performance of it is contrary to the interest of the animal. Thus the stomach always converts food into chyme, even when the food is of such a nature that the process of digestion will be retarded rather than promoted by the change. If warm milk, for instance, or warm blood, be thrown into the stomach, they are always decomposed by that organ, and converted into chyme; yet these substances are much more nearly assimilated to the animal before the action of the stomach than after it. The same thing happens when we eat animal food.

Every assimilating organ produces a specific change.

On the other hand, a substance introduced into an organ employed in assimilation, if it has undergone precisely the change which that organ is fitted to produce, is not acted upon by that organ, but passed on unaltered.

And no other.

## Book V.

ed to the next assimilating organ. Thus it is the office of the intestines to convert chyme into chyle. Accordingly, whenever chyme is introduced into the intestines, they perform their office, and produce the usual change; but if chyle itself be introduced into the intestines, it is absorbed by the lacteals without alteration. The experiment, indeed, has not been tried with true chyle, because it is scarce possible to procure it in sufficient quantity; but when milk, which resembles chyle pretty accurately, is thrown into the jejunum, it is absorbed unchanged by the lacteals\*.

Again, the office of the blood-vessels, as assimilating organs, is to convert chyle into blood. Chyle, accordingly, cannot be introduced into the arteries without undergoing that change; but *blood* may be introduced from another animal without any injury, and consequently without undergoing any change. This experiment was first made by Lower, and it has since been very often repeated.

Also, if a piece of fresh muscular flesh be applied to the muscle of an animal, they adhere and incorporate without any change, as has been sufficiently established by the experiments of Mr J. Hunter; and Buvina has ascertained, that fresh bone may, in the same manner, be engrafted on the bones of animals of the same or of different species†.

Foreign substances may be incorporated with the body.

In short, it seems to hold, at least as far as experiments have hitherto been made, that foreign substances may be incorporated with those of the body, provided they be precisely of the same kind with those to which

\* Fordyce on *Digestion*, p. 189.

† *Phil. Mag.* vi. 352.



they are added, whether fluid or solid. Thus chyle may be mixed with chyle, blood with blood, muscle with muscle, and bone with bone. The experiment has not been extended to the other animal substances, the nerves, for instance; but it is extremely probable that it would hold with respect to them also.

Chap. III.

On the other hand, when substances are introduced into any part of the body which are not the same with that part, nor the same with the substance upon which that part acts, provided they cannot be thrown out readily, they destroy the part, and perhaps even the animal. Thus foreign substances introduced into the blood very soon prove fatal; and introduced into wounds of the flesh or bones, they prevent these parts from healing.

Although the different assimilating organs have the power of changing certain substances into others, and of throwing out the useless ingredients, yet this power is not absolute, even when the substances on which they act are proper for undergoing the change which the organs produce. Thus the stomach converts food into chyme, the intestines chyme into chyle, and the substances which have not been converted into chyle are thrown out of the body. If there happen to be present in the stomach and intestines any substance which, though incapable of undergoing these changes, at least by the action of the stomach and intestines, yet has a strong affinity, either for the whole chyme and chyle, or for some particular part of it, and no affinity for the substances which are thrown out, that substance passes along with the chyle, and in many cases continues to remain chemically combined with the substance to which it is united in the stomach, even after that substance

Powers of the assimilating organs limited.



Book V.

has been completely assimilated, and made a part of the body of the animal. Thus there is a strong affinity between the colouring matter of madder and phosphate of lime. Accordingly, when madder is taken into the stomach, it combines with the phosphate of lime of the food, passes with it through the lacteals and blood vessels, and is deposited with it in the bones, as was proved by the experiments of Duhamel. In the same manner, musk, indigo, &c. when taken into the stomach, make their way into many of the secretions.

Assimilation a chemical process ;

These facts show us that assimilation is a chemical process from beginning to end ; that all the changes are produced according to the laws of chemistry ; and that we can even derange the regularity of the process by introducing substances whose mutual affinities are too strong for the organs to overcome.

It cannot be denied, then, that the assimilation of food consists merely in a certain number of chemical decompositions which that food undergoes, and the consequent formation of certain new compounds. But are the *agents* employed in assimilation merely chemical agents ? We cannot produce any thing like these changes on the food out of the body, and therefore we must allow that they are the consequence of the action of the animal organs. But this action, it may be said, is merely the secretion of particular juices, which have the property of inducing the wished-for change upon the food : and this very change would be produced out of the body, provided we could procure these substances, and apply them in proper quantity to the food. If this supposition be true, the specific action of the vessels consists in the secretion of certain substances : consequently the cause of this secretion is the

assimilation. Now, can the *cause* of this secretion be shown to be merely a chemical agent? Certainly not. For in the stomach, where only this secretion can be shown to exist, it is not always the same, but varies according to circumstances. Thus eagles at first cannot digest grain, but they may be brought to do it by persisting in making them use it as food. On the contrary, a lamb cannot at first digest animal food, but habit will also give it this power. In this case, it is evident that the gastric juice changes according to circumstances.

The presence of some agent, different from a mere chemical power, will be still more evident, if we consider the immunity of the stomach of the living animal during the process of digestion. The stomach of animals is as fit for food as any other substance. The gastric juice, therefore, must have the same power of acting on it, and of decomposing it, that it has of acting on other substances; yet it is well known that the stomach is not affected by digestion while the animal retains life; though, as Mr Hunter ascertained, the very gastric juice which the living stomach secretes, often dissolves the stomach itself after death. Now what is the power which prevents the gastric juice from acting on the stomach during life? Certainly neither a chemical nor mechanical agent, for these agents must still retain the same power after death. We must, then, of necessity conclude, that there exists in the animal an agent very different from chemical and mechanical powers, since it controls these powers according to its pleasure. These powers, therefore, in the living body, are merely the servants of this superior agent, which directs them so as to accomplish always one par-

But the agent not chemical.

Book. V.

ticular end. This agent seems to regulate the chemical powers, chiefly by bringing only certain substances together which are to be decomposed, and by keeping at a distance those substances which would interfere with or diminish, or spoil the product, or injure the organs; and we see that this separation is always attended to even when the substances are apparently mixed together: For the very same products are not obtained, which would be obtained by mixing the same substances together out of the body, that are produced by mixing them in the body; consequently all the substances are not left at full liberty to obey the laws of their mutual affinities. The superior agent, however, is not able to exercise an unlimited authority over the chemical powers; sometimes they are too strong for it: some substances, accordingly, as madder, make their way into the system; while others, as arsenic, decompose and destroy the organs of the body themselves.

But it is not in digestion alone that this superior agent makes the most wonderful display of its power. it is in the last part of assimilation that our admiration is most powerfully excited. How comes it that the precise substances wanted are always carried to every organ of the body? How comes it that fibrin is always regularly deposited in the muscles, and phosphate of lime in the bones? And what is still more unaccountable, how comes it that prodigious quantities of some one particular substance are formed and carried to a particular place, in order to supply new wants which did not before exist? A bone, for example, becomes diseased and unfit for the use of the animal; a new bone therefore is formed in its place, and the old one is



carried off by the absorbents. In order to form this new bone, large quantities of phosphate of lime are deposited in a place where the same quantity was not before necessary. Now, who informs this agent that an unusual quantity of phosphate of lime is necessary, and that it must be carried to that particular place? Or, granting, as is most probable, that the phosphate of lime of the old bone is partly employed for this purpose, who taught this agent that the old bone must be carried off, new-modelled, and deposited and assimilated anew? The same wonders take place during the healing of every wound, and the renewing of every diseased part.

But neither in this case is the power of this agent over the chemical agents which are employed absolute. We may prevent a fractured bone from healing, by giving the patient large quantities of acids. And unless the materials for new-wanted substances be supplied by the food, they cannot in many cases be formed at all. Thus the canary bird cannot complete her eggs unless she be furnished with lime.

As this agent which characterises living bodies does not appear to act according to the principles of chemistry, any inquiry into its nature would be foreign to the subject of this Work. Physiologists have given it the name of the *living* or *animal* principle; and to them I beg leave to refer the reader.

Nature of  
this agent.

Besides the different organs of the body, the blood is also employed in forming all the different secretions which are necessary for the purposes of the animal economy. These have been enumerated in the last Chapter. The process is similar to that of assimilation, and undoubtedly the agents in both cases are the same; but

2. Blood  
furnishes  
the materials of  
secretion.



Book V.

Animals  
decay and  
die.

we are equally ignorant of the precise manner in which secretion is performed as we are of assimilation.

After these functions have gone on for a certain time, which is longer or shorter according to the nature of the animal, the body gradually decays, at last all in functions cease completely, and the animal dies. The cause of this must appear very extraordinary, when we consider the power which the animal has of renewing decayed parts; for it cannot be doubted that death proceeds, in most cases at least, from the body becoming incapable of performing its functions. But if we consider that this power is limited, and that it must cease altogether when those parts of the system begin to decay which are employed in preparing materials for future assimilation, our surprise will, in some measure, cease. It is in these parts, in the organs of digestion and assimilation, accordingly, that this decay usually proves fatal. The decay in other parts destroys life only when the waste is so rapid that it does not admit of repair.

What the reason is that the decay of the organs causes death, or, which is the same thing, causes the living principle either to cease to act, or to leave the body altogether, it is perfectly impossible to say, because we know too little of the nature of the living principle, and of the manner in which it is connected with the body. The last is evidently above the human understanding; but many of the properties of the living principle have been discovered: and were the facts already known properly arranged, and such general conclusions drawn from them as their connection with each other fully warrant, a degree of light would be thrown

upon the animal economy, which those who have not attended to the subject are not aware of.

No sooner is the animal dead, than the chemical and mechanical agents, which were formerly servants, usurp the supreme power, and soon decompose and destroy that very body which had been in a great measure reared by their means. But the changes which take place upon animal bodies after death, are too important to be passed over slightly. They shall therefore form the subject of the next Chapter.

## CHAP. IV.

OF THE DECOMPOSITION OF ANIMAL  
BODIES.  

---

THE rapidity with which animal bodies undergo decomposition, and the disgusting fœtor which accompanies this decomposition, have long been considered some of their most striking peculiarities. This spontaneous destruction is denominated *putrefaction*. Considerable attention has been paid to it by chemists. Buchar and Stahl have described with fidelity the phenomena with which it is attended, and the circumstances necessary for its taking place. Several curious remarks on it were made by Boyle and Beale \*. To Sir John Pringle we are indebted for some important experiments on the method of retarding putrefaction†; neither are the experiments of Dr Macbride less valuable, though the consequences which he drew from them were enormous. We are indebted also to Crell and Priestley for many valuable facts; and to Berthollet and Lavoisier for the first attempts to determine the real changes

---

\* *Phil. Trans.* iv. 1135.

† *Ibid.* xlv. 480. &c.

which take place, and the manner in which the new products which appear during putrefaction are formed. But notwithstanding the labours of these philosophers, and of many others, much is still wanting to enable us to trace the complicated changes which take place during putrefaction, and to account for them in a satisfactory manner.

It has been ascertained long ago, that putrefaction never takes place in those animal substances which contain only two or three ingredients, such as oils, resins, sugar; they must always be more complicated in their texture: and perhaps in all cases a mixture of two or more compound bodies is necessary for speedy decomposition. But however complicated the animal substance may be, it does not putrefy unless moisture be present; for dry animal substances are not susceptible of alteration. A certain degree of heat is also necessary. Animal bodies may be kept without decomposing for any length of time at the freezing temperature. In general, the higher the temperature the more rapid is the putrefaction, provided the heat be not great enough to reduce the animal body to dryness. It has been observed, too, that putrefaction advances with more rapidity in the open air; but exposure to the air is not necessary, though it modifies the decomposition.

Conditions  
requisite  
for putre-  
faction.

When these conditions are observed, and dead animal matter is left to itself, its colour becomes gradually paler, and its consistence diminishes: if it be a solid part, such as flesh, it softens, and a serous matter sweats out, whose colour quickly changes; the texture of the part becomes relaxed, and its organization is destroyed; it acquires a disagreeable smell; the substance gradually sinks down, and is diminished in bulk; its smell

Putrefac-  
tion  
air.



Book V.

becomes strongly ammoniacal. If the subject be contained in a close vessel, the progress of putrefaction in this stage seems to slacken; no other smell but that of a pungent alkali is perceived; the matter effervesces with acids, and converts syrup of violets to a green. But if the communication with the air be admitted, the urinous exhalation is dissipated, and a peculiar putrid smell is spread around with a kind of impetuosity, a smell of the most insupportable kind, which lasts a long time, and pervades every place, affecting the bodies of living animals after the manner of a ferment, capable of altering the fluids: this smell is corrected, and as it were confined by ammonia. When the latter is volatilized, the putrefactive process becomes active a second time, and the substance suddenly swells up, becomes filled with bubbles of air, and soon after subsides again. Its colour changes, the fibrous texture of the flesh being then scarcely distinguishable; and the whole is changed into a soft brown or greenish matter, of the consistence of a poultice, whose smell is faint, nauseous, and very active on the bodies of animals. The odorant principle gradually loses its force, the fluid portion of the flesh assumes a kind of consistence, its colour becomes deeper, and it is finally reduced into a friable matter, rather deliquescent: which being rubbed between the fingers, breaks into a coarse powder like earth. This is the last state observed in the putrefaction of animal substances; they do not arrive at this term but at the end of a considerable time\*.

Products.

During this decomposition a variety of gaseous bo-

---

\* Fourcroy.

dies are emitted : these vary according to the substance exposed to putrefaction ; but they consist chiefly of hydrogen gas, holding sulphur, phosphorus, and carbon in solution ; of ammonia, water, and carbonic acid, and perhaps also of azotic gas. Nitric acid seems in some cases to be formed and emitted. The earthy-like residuum, which remains after the decomposition is completed, consists of the fixed parts of the animal substance, mixed with charcoal, oil, and ammonia. Thus it appears that putrefaction consists in a total decomposition of the animal body ; the elements of which combine together two and two, and thus form a new set of less complicated bodies. But any attempt to explain the manner in which these changes take place would be exceedingly imperfect indeed ; not only because we are ignorant of the strength of the affinities of the different elementary parts of animal bodies for each other, but because we do not even know the manner in which these elements are combined, and consequently we cannot know by what particular forces these compounds are destroyed.

In carcases buried in the earth, putrefaction takes place much more slowly ; but it is scarcely possible to observe its progress with accuracy. The abdomen is gradually dilated with elastic fluids, which make their appearance in it, and at last it bursts and discharges a horribly fetid and noxious gas ; at the same time a dark coloured liquid flows out. If the earth be very dry, and the heat considerable, the moisture is often absorbed so rapidly, that the carcase, instead of putrefying, dries, and is transformed into what is called a *mummy*.

Putrefaction under ground.

Such are the phenomena when dead bodies are left

## Book V.

Putrefac-  
tion of ac-  
cumulated  
animal mat-  
ter.

to putrefy separately : but when great numbers of car-  
cases are crowded together in one place, and are  
abundant as to exclude the action of external air and  
other foreign agents, their decomposition is entirely the  
consequence of the reciprocal action of their ingredients  
themselves upon each other, and the result is very dif-  
ferent. The body is not entirely dissipated or reduced  
to mould, but all the soft parts are found diminished  
remarkably in size, and converted into a peculiar *sapo-  
naceous matter*. This singular change was first ac-  
tually observed in the year 1786.

Converted  
into a *sapo-  
naceous*  
matter.

The burial ground of the Innocents in Paris having  
become noxious to those who lived in its neighbour-  
hood, on account of the disagreeable and hurtful odour  
which it exhaled, it was found necessary to remove the  
carcases to another place. It had been usual to dig  
very large pits in that burial ground, and to fill them  
with the carcases of the poorer sort of people, each in  
its proper bier ; and when they were quite full, to  
cover them with about a foot deep of earth, and to dig  
another similar pit, and fill it in the same manner.  
Each pit held between 1000 and 1500 dead bodies. It  
was in removing the bodies from these pits that this  
*saponaceous* substance was found. The grave-digger  
had ascertained, by long experience, that about thirty  
years were required before all the bodies had undergone  
this change in its full extent \*. Every part of the body  
acquired the properties of this substance. The intestines  
and viscera of the thorax had completely disappeared ;  
but what is singular enough, the brain had less

\* Fourcroy, *Ann. de Chim.* v. 154.



but little of its size or appearance, though it was also converted into the same substance. Chap. IV.

This saponaceous matter was of a white colour, soft and unctuous to the touch, and melted, when heated, like tallow. It exhibited all the properties of a *soap*, containing, however, an excess of fatty matter. Fourcroy, who analysed it, found that it was composed of a fatty matter combined with ammonia, and that it contained also some phosphate of lime and ammonia. Diluted acids decomposed it, and separated the fatty matter: alkalies and lime, on the other hand, drove off the ammonia. When exposed to the air it gradually lost its white colour; the ammonia, in a great measure, evaporated; and what remained had something of the appearance of wax. It absorbed water with great avidity, and did not part with it readily. Its white colour was owing to the presence of that liquid. The oily matter, when separated by means of a diluted acid, was concrete, and of a white colour, owing to the mixture of a quantity of water. When dried, it acquires a greyish-brown colour, a lamellar and crystalline texture, like that of spermaceti; but if it has been rapidly dried, it assumes the appearance of wax. It melts when heated to  $126^{\circ}$ ; when properly purified, by passing it through a linen cloth while fluid, it has scarcely any smell. Alcohol does not act upon it while cold, but at the temperature of  $120^{\circ}$  it dissolves it: when the solution cools, the fatty matter precipitates, and forms a gritty mass. With alkalies it forms a soap; and when set on fire it burns precisely like oil or fat, only that it exhales a more unpleasant odour\*.

---

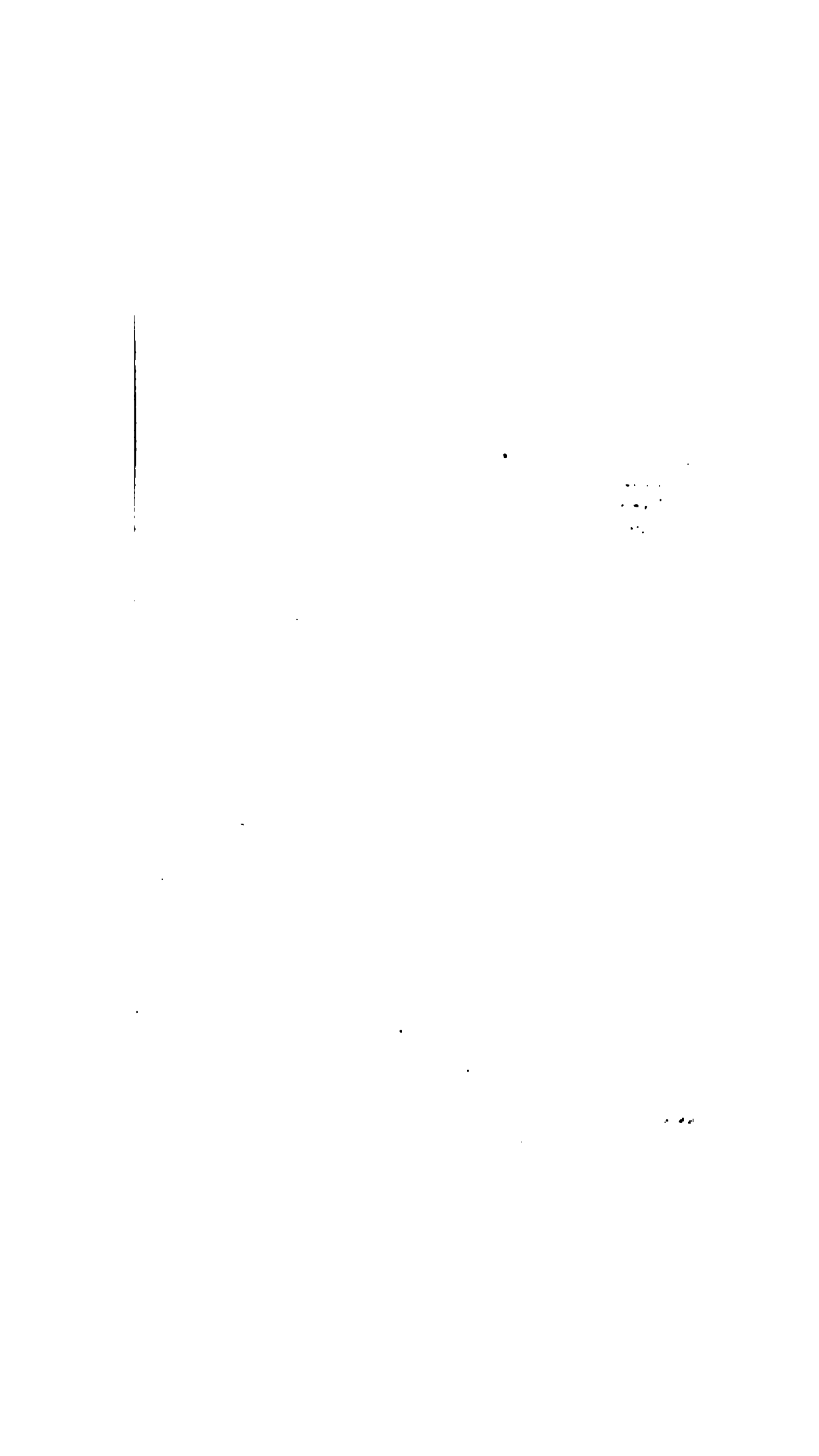
\* Fourcroy, *Ann. de Chim.* viii. 17. A set of experiments on a simi-



water, or preventing that liquid from acting upon these bodies in its usual manner. In this way the acids, sugar, alcohol, &c. seem to prevent or retard putrefaction.

3. It is well known that common salt is a powerful antiseptic. Hence the practice of salting meat, and the length of time which meat that has undergone this operation may be kept. Several other salts, especially nitre, possess the same property. In what manner these bodies act has not been ascertained; but they undoubtedly produce some chemical change upon the meat; for they alter its taste, its colour, and other sensible properties.

4. Many aromatics, such as camphor, resins, volatile oils, bitumens, and other similar bodies, act with considerable efficacy in preserving animal bodies from putrefaction. Hence their utility in embalming. In what the action of these substances consists has not been ascertained. Part of their efficacy is doubtless owing to the rapidity with which the animal substances to which they are applied lose their moisture; and something may be ascribed likewise to their odour, which keeps insects at a distance, and thus prevents the lodging of excrementitious matter, which always acts powerfully as a putrefactive ferment.



## APPENDIX.

---

**I**N a science of so extensive a nature as CHEMISTRY, which is cultivated in so many different countries, and by so numerous a body of eminent philosophers, new facts must be continually expected; and our opinions and theories, which serve merely as stepping-stones to conduct us to truth, must, in consequence, be frequently altered and modified anew. Since the commencement of this Edition a considerable time has elapsed, during which many important additions have been made to our knowledge. Such of these discoveries as could be introduced into the preceding Work have been already explained; those which were not published soon enough to be inserted in their proper place, or which did not come soon enough to hand, I think it necessary to enumerate in an Appendix, that the reader may have as complete a view as possible of the present state of the science. In this enumeration I shall follow exactly the order of arrangement which has been adopted in the Work itself.

Book I.  
Division I.

PART I.—BOOK I.—DIVISION I.  
CHAP. II. OF SIMPLE COMBUSTIBLES, Vol. I. p. 33.

SINCE this Chapter was printed several important experiments have been made on the simple combustibles, and a new one has been discovered and added to the list.

I. Carbon.

MR DAVY has exposed plumbago, well burnt charcoal, and the diamond, to the action of a galvanic battery in a Torricellian vacuum. Plumbago yielded no gaseous product whatever, neither was any change produced upon it when heated with potassium, excepting that it appeared to combine with that metal. Charcoal, in the Torricellian vacuum, gave out an intense purple light, and emitted some inflammable gas, 100 measures of which absorbed 75 measures of oxygen gas, and produced 37.5 measures of carbonic acid. These proportions correspond with those of no known gas. Potassium and charcoal when heated together combine, but evolve no gas. When the diamond and potassium are heated together in glass tubes, no elastic fluid is given out, but the diamond soon blackens, and scales seem to detach themselves from it. The potassium when thrown into water evolves less hydrogen, indicating that it has absorbed a portion of oxygen. From these experiments Mr Davy infers, that plumbago consists of pure carbon combined with about  $\frac{1}{10}$ th of iron, that charcoal contains a little hydrogen, and that the diamond contains a



little oxygen\*. But it appears, from the experiments of Thenard and Gay Lussac, that plumbago likewise contains hydrogen. For when oxymuriatic acid gas is passed over red-hot plumbago, it is converted partly into common muriatic acid gas. Now water is an essential constituent of that gas; of course water must have been formed, and the hydrogen must have been supplied by the plumbago. By a similar experiment these gentlemen ascertained the existence of hydrogen in charcoal†. Pure carbon then, unless hydrogen be admitted as a constituent of it, still continues unknown.

Brugnatelli has endeavoured to show that charcoal has the property of combining with oxygen, and with hydrogen, without altering its appearance much, and that the new compounds possess different chemical properties from pure charcoal‡.

Berthollet has lately exposed charcoal to a violent heat in porcelain and glass retorts, and shown that the gas, which comes over, contains a mixture of azote. The proportion of this gas increases as the distillation proceeds. Hence he concludes that azote is one of the constituents of charcoal§. When the heavy inflammable airs obtained from charcoal, and from various animal and vegetable bodies, are detonated with oxygen, there is always a gaseous residue to be observed, which will not burn, and which is not absorbed nor altered by any substance applied to it or mixed with it. This residue is what Berthollet considers as azote. It is recognised merely by its negative properties, which seem

Azote from  
charcoal.

\* *Phil. Trans.* 1809.

† *Ann. de Chim.* lxi. 311.

*Vol. V.*

‡ *Mém. d'Arcueil*, ii. 344.

§ *Mém. d'Arcueil*, ii. 484.

pit-coal frequently contains small quantities of sulphureted hydrogen, carbonic acid, and olefiant gas, and he has supposed that pure hydrogen gas is often an ingredient in the lightest gases. But this last supposition I consider as very unlikely to be true; for hydrogen has such a tendency to combine with carbon, that it can scarcely be evolved pure when in contact with charcoal. As to Berthollet's second opinion, that the heavy inflammable airs are all oxycarbureted hydrogen, I must acknowledge that every one of them examined by myself, and I have analysed a good many, contained oxygen. But this is not sufficient to decide the question; because, if carbonic oxide contains no hydrogen, and Berthollet himself allows that it sometimes is nearly free from it, we have only to suppose a mixture of that gas, to account for the oxygen which we find in the gases examined. Upon the whole, the subject is still so obscure, that many new experiments are necessary before our opinions can be fixed\*.

## II. Phosphorus.

FROM Mr Davy's experiments there is reason to conclude, that phosphorus contains both hydrogen and oxygen. When phosphorus is exposed to the action of a powerful galvanic battery, a quantity of phosphureted hydrogen gas is emitted, sometimes amounting to four times the bulk of the phosphorus acted upon. When phosphorus and potassium are fused together, they combine with a most vivid light and intense ignitions

---

\* *Mém. d'Arcueil*, ii. 68.

Book I.  
Division I.

One grain of potassium :  
ring this combination, g  
phureted hydrogen gas  
upon the phosphureted  
phosphureted hydrogen  
potassium with 3 grain  
ing fusion 0.25 grain  
and when treated with  
more of the same gas  
portion of phosphurete  
rus is increased, seems  
gen in the phosphorus

## II

Mr DAVY has shown  
hydrogen, and render  
likewise present in it.  
the galvanic battery, st  
ted for a very long pe  
Davy obtained a quan  
the bulk of the sulphu  
pose, (as seems to fo  
ments), that sulphurete  
bulk of hydrogen gas ;  
times lighter than com  
gen emitted in this c  
part of the weight of  
is heated with sulphur,



diluted muriatic acid, sulphureted hydrogen gas is emitted, but less in quantity than the bulk of the hydrogen gas which the potassium would have given out when treated with water, and the quantity of sulphureted hydrogen gas is diminished by increasing that of the sulphur. Now this cannot well be explained, without supposing that the sulphur has given out oxygen to the potassium. Mr Davy has shown, that the sulphur in sulphureted hydrogen gas is in its usual state; yet when potassium is heated in this gas, it burns and is partly converted into potash; hence it must have absorbed oxygen from the gas, and hence the sulphur in that gas seems to contain oxygen \*.

#### IV. Boracium.

This substance, which constitutes the base of boracic acid, has been recently separated and examined, in consequence of the new analytical methods pointed out by Mr Davy. Soon after his discovery of the method of decomposing the fixed alkalies, he exposed boracic acid to the action of the galvanic battery, and observed that a black matter was deposited upon the negative wire, which he considered as the basis of boracic acid. But he did not prosecute the discovery at the time. In the summer of 1808, Messrs Gay Lussac and Thénard succeeded in decomposing boracic acid, by heating it in a copper tube along with potassium. They examined its base, and published an account of its pro-

Analysis of  
boracic  
acid.

---

\* *Phil. Trans.* 1809.



2. When heated in the open air, or in contact with oxygen gas, it takes fire at a temperature below the boiling point of olive oil, and burns with a red light and scintillations like charcoal, and is converted into boracic acid. It is difficult to burn it completely, because the boracic acid first formed, furnishes a vitreous crust, which protects the residue of the boracium from the action of the oxygen. When this crust is washed off, the boracium is found in the state of a black matter, which does not take fire till it be heated nearly to redness, and which absorbs less oxygen during its combustion than the olive coloured matter. Hence it is probable, that this black matter is an oxide of boracium.

Gay Lussac and Thenard have concluded from their experiments, that 100 parts of boracium, when burnt, combine with 50 parts of oxygen, and form 150 of boracic acid. Mr Davy, on the other hand, has concluded from his experiments, that boracic acid is composed of 100 parts of boracium, and 200 of oxygen; and the black oxide of boracium, of 100 boracium, and 33 of oxygen. I have not had an opportunity of seeing the way in which the French chemists performed their experiments, as no details are given, either in the *Journal de Physique* (lxvii. 393), or in the *Memoires d'Arcueil* (ii. 311.), in both of which their account of boracium has been published. Mr Davy's experiments were made with great care; and though absolute precision in a case of this nature is not to be expected, they may, without hesitation, be received as at least a pretty close approximation to it. He found that 30 grains of potassium decomposed such a quantity of boracic acid, as left 2.4 grains of boracium,

Composi-  
tion of bo-  
racic acid.

and heated to whiteness, it assumes the lustre of plumbago, and becomes a conductor of electricity. In this state it effervesces slightly with water. But if it be exposed to the air for a few minutes it becomes olive, loses its conducting power, and its property of effervescing with water. When intensely heated, mixed with a little potassium, and covered with iron filings, it combines with the iron, and forms a dark metallic mass, which conducts electricity, and effervesces slightly with water. Such are the experiments which have led Mr Davy to suppose boracium to contain oxygen, and to conjecture that the pure base is of a metallic nature.

CHAP. III. SIMPLE INCOMBUSTIBLES.—SECT. I.  
AZOTE.—Vol. I. p. 104.

FROM the recent experiments of Mr Davy there are strong reasons to conclude that azote is a compound; but as these experiments have not yet led to results perfectly satisfactory, I shall give a detail of them rather under the head of ammonia than in this place, because they consist in treating that alkaline gas with potassium.

II. Muriatic acid.

MANY experiments on this acid have been recently made by Davy\*, Thenard and Gay Lussac†, and Berthollet‡, which have brought to light some singular

---

\* *Phil. Trans.* 1809.

† *Mém. d'Arcueil*, ii. 339.

‡ *Jour. de Phys.* lxiv. 215.



hydrogen gas is developed, as appears when potassium is treated with water.

Chap. III.

2. Various attempts were made, both by Davy and the French chemists, to obtain muriatic acid gas free from water, by decomposing a muriate by means of some substance which contained no water. But none of these attempts were successful. When dry muriate of soda is mixed with vitreous boracic or phosphoric acids intensely heated, no decomposition whatever takes place; but if the vapour of water be brought in contact with the mixture, muriatic acid gas is disengaged abundantly. In the same way Mr Davy tried ineffectually to decompose common salt by means of dry sulphate of iron, though that salt in its ordinary state decomposes common salt very readily. When common salt and siliceous sand or dry clay are strongly heated, no decomposition takes place; but when the vapour of water comes in contact with these bodies, muriatic acid gas is disengaged in abundance. Corrosive sublimate is a salt which contains muriatic acid without any mixture of water. Attempts were made to obtain it from this salt by distillation with phosphorus; a liquid came over, which proved a compound of phosphorus and muriatic acid, and to which Thenard and Gay Lussac, the discoverers of it, have given the name of *phosphureted muriatic acid*. Mr Davy endeavoured to deprive this liquid of its phosphorus by means of potassium; but when the two substances were heated together, the consequence was a violent explosion, which destroyed the vessels. He succeeded indeed in depriving very minute quantities of this liquid of a considerable portion of their phosphorus, but the quantities were too small to determine exactly their properties. When the fuming

Acid cannot be obtained pure.

Book I.  
Division I.

Oxymuriatic acid

Loses its  
elasticity  
when de-  
prived of  
oxygen,

muriate of tin of Libavius is distilled with sulphur, there comes over a quantity of sulphureted muriatic acid, from which the muriatic acid cannot be separated free by any process hitherto tried.

3. Oxymuriatic acid gas, as appears from the experiments both of Davy and the French chemists, contains no water as an essential constituent. It may be made perfectly dry by the usual hygrometrical methods. If it could be deprived of its oxygen, therefore, without losing its elasticity, muriatic acid gas would be obtained perfectly free from water. Experiments were made with that view both by Davy and the French chemists, but they were all unsuccessful. Mr Davy attempted to free oxymuriatic acid gas from its oxygen by means of phosphorus. The phosphorus, as is well known, burns spontaneously in this gas. During the combustion no muriatic acid gas was evolved. Two substances were obtained, a white sublimate which collected at the top of the retort, and a fluid as limpid as water, which trickled down its sides; the first was in considerable quantity, the last only in the quantity of a few drops. The sublimate emitted fumes of muriatic acid when exposed to the air. When brought in contact with water, it evolved muriatic acid gas, and left phosphoric acid and muriatic acid dissolved in the water. It was a non-conductor of electricity, and did not burn when heated, but sublimed completely at the temperature of  $212^{\circ}$ . It seems a compound of muriatic and phosphoric acids in their dry states. The fluid had a pale greenish yellow colour, and was very limpid. It disappeared rapidly in the open air, emitting dense fumes with a smell somewhat different from that of muriatic acid. It reddened litmus paper in its common



state, but had no effect upon paper which had been well dried. It was a non-conductor of electricity. It seems a compound of phosphorous and muriatic acids.

The action of sulphur to deprive oxymuriatic acid of its oxygen, was tried both by Davy and Thenard and Gay Lussac, but without success. No gas was evolved, but sulphureted muriatic acid was formed.

When this gas is passed over well burnt charcoal heated to redness, a little muriatic acid gas comes over at first, but after a certain time the oxymuriatic acid gas passes through the red-hot charcoal without any change whatever. Hence it is obvious, that the decomposition, at first, is owing to the formation of water by the union of the hydrogen of the charcoal with the oxygen of the gas. Accordingly, the muriatic acid gas obtained contains its usual quantity of water. Hence it appears, that the action of oxymuriatic acid gas is the most powerful instrument known for depriving charcoal of the whole of the hydrogen which it contains.

Unless water be formed.

Thenard and Gay Lussac have shown, that hydrogen gas, olefiant gas, and other similar gases, decompose oxymuriatic acid gas simply in consequence of the hydrogen which they contain, and which forms water by uniting with the oxygen of that acid gas. They have shown that gases which contain no hydrogen, as nitrous gas, produce no change upon oxymuriatic acid gas, unless water be present. As carbonic oxide is not decomposed by it, this is additional proof that hydrogen is not one of the constituents of that gas. Thus it appears that oxymuriatic acid is one of the most intimate combinations known, and that the presence of water, or the formation of it, is almost always necessary for its decomposition.

Book I.  
Division 1.

Attempt to  
decompose  
muriatic  
acid.

4. As all attempts to procure muriatic acid gas free from water had failed, Mr Davy attempted to deprive the phosphureted muriatic acid, formed by distilling a mixture of phosphorus and corrosive sublimate, of its phosphorus. This he in some measure effected by distilling it repeatedly from potassium, which combined with the phosphorus. Ten or twelve drops of the liquor, that had been thus treated, were introduced into a small plate glass retort containing six grains of potassium. The retort was exhausted after having been twice filled with hydrogen gas. The liquid was made to boil, and the retort kept warm till the whole had disappeared as elastic vapour. The potassium was then heated by a spirit lamp. It scarcely had melted when it burst into a most splendid combustion, and the retort was destroyed. After many failures Mr Davy was enabled at last to obtain the results. No elastic fluid appeared to be evolved; a solid mass remained of a greenish colour at the surface, but dark grey within; it was extremely inflammable, and often burnt spontaneously when exposed to the air; when thrown upon water it produced a violent explosion, with a smell like that of phosphureted hydrogen. In the residue of its combustion were found muriate of potash, and phosphate of potash. This splendid combustion of potassium in the elastic fluid produced from phosphureted muriatic acid, is extremely singular, and cannot well be accounted for without supposing that the muriatic acid contributes to produce the effect. Were that admitted, it would follow that the muriatic acid had been decomposed by the process, and its oxygen absorbed by the potassium. But more satisfactory experiments will be requisite before so very important a consequence can be admitted.

5. From the experiments above detailed, there is reason to consider the muriatic as the most powerful of all the acids. It seems impossible to separate it from any of the bases, by other acids unless water be present.

Chap. IV.

#### CHAP. IV. OF METALS.—Vol. I. p. 131.

SEVERAL additions have been made to the chemical history of the metals since this Chapter was printed. Of these additions I shall now give a detail.

##### I. Iron.

I HAVE committed a mistake in stating the quantity of oxygen in the oxides of this metal, which has lately been pointed out by Mr Hassenfratz \*. The mistake was owing to the ambiguous method of expression used by Proust, the chemist on whose experiments I deduced the composition of these oxides. In consequence of Mr Hassenfratz's paper I have been induced to make a set of experiments on the subject, with as much care as possible to obtain exact results. The black oxide of iron I found composed of 100 parts of iron, and 27.5 of oxygen, or 78.5 iron

Oxides of iron.

21.5 oxygen

---

100.0

---

\* *Ann. de Chim.* lxx. 145.



Book I.  
Division I.

The red oxide I found composed of 100 iron and 6  
oxygen, or nearly of 69 iron

31 oxygen

---

100

These results do not differ much from the proportions obtained by others. They destroy the conclusion which I have drawn, respecting an oxide of iron containing less oxygen than the black oxide. What I took for a new oxide was in all probability the black oxide itself. They render it necessary to alter the weight of an atom of iron, as deduced in the third volume, p. 528, from the mistaken ratio between the oxygen and metal contained in the oxides. We may conceive that there are three oxides of iron; the protoxide, still unknown, composed of 100 metal and 15 oxygen; the deutoxide, or black oxide, composed of 100 metal,  $+2 \times 15$  oxygen; and the peroxide, or red oxide, composed of 100 metal  $+3 \times 15$  oxygen. If the first oxide be supposed a compound of an atom of metal, and an atom of oxygen, it is obvious that an atom of iron will weigh 40, supposing an atom of oxygen to weigh 6.

I have examined Thenard's *white oxide of iron* with great care, but have always found abundance of sulphuric acid. When this acid is separated, the white colour always disappears, and it becomes green, black, and at last red.

## II. Lead.

DESCOTILS has published some experiments upon the action of the different gases on sulphuret of lead, which deserve attention, because they point out the



sources of loss in the common methods of extracting lead from its ores. Chap. IV.

When sulphuret of lead is exposed to a strong heat in a porcelain crucible, some sulphur is separated, a considerable portion of the sulphuret is sublimed, and there remains a subsulphuret of lead, which possesses ductility. When sulphurous acid gas and carbonic acid gas are passed through red-hot sulphuret, no change is produced, excepting that a portion of the sulphuret is sublimed, being carried off by the mechanical action of the gases. When steam is passed through sulphuret of lead, the sulphuret is sublimed in considerable quantity. The residue, besides sulphuret of lead, contains sulphate and lead in the metallic state. During the process hydrogen gas and sulphurous acid gas are disengaged. When hydrogen gas is passed through red-hot sulphuret of lead, some of the sulphuret is volatilized, but the greatest part is reduced to the state of metallic lead, and the hydrogen passes in the state of sulphureted hydrogen. When air is passed slowly over red-hot sulphuret of lead, almost the whole is converted into sulphate; but if it be passed rapidly, a white fume issues, having the smell of sulphurous acid, and depositing a fine white powder, which consists of sulphate of lead. Hence the great loss which is sustained when galena is treated in the open air, as is the case in all the operations usually practised in the reduction of lead ores. Descotils recommends iron as the best method of separating sulphur from galena. This metal is unfortunately too expensive for the purpose, but he recommends a trial of the rich ores of iron, pre-

Book I.  
Division I.

vously reduced to the metallic state by heating them to redness with charcoal\*.

### III. Nickel.

SOME observations on nickel have been published by Professor Tourte of Berlin, made during the construction of a magnetic needle of nickel. It admits of a fine polish, and does not soon lose its lustre when exposed to the air. Its colour, when polished, is intermediate between that of platinum and steel. When heated to redness it becomes greenish grey. When its temperature is slowly raised, it undergoes a suite of changes of colour similar to polished steel. It becomes first light yellow, then deep yellow, light violet blue, deep violet blue, and last of all greyish blue. The colours have not the same intensity as those of steel. Tourte found the specific gravity of pure nickel, at the temperature of 55°, to be 8.402; but by strong hammering it was reduced to 8.032. He affirms that nickel wire burns like iron wire in oxygen gas; but when Gehlen repeated the experiment it did not succeed. Nickel may be drawn out into fine wire, but it is difficult to solder it, probably because its surface is apt to oxidize. It yields to the file, but soon destroys the file. It is a better conductor of heat than zinc or iron. The addition of a little arsenic does not destroy its magnetic properties. It is very easily converted into a magnet, and retains its magnetic virtue. The inclination of a

---

\* *Mém. d'Arcueil*, iii. 424.

magnetic needle of nickel is the same as that of one of steel \*.

Chap. IV.

#### IV. Vestium.

It has been announced on the continent that a German chemist has discovered, in crude platina, a new metal, to which the name of *vestium* has been given †. No particulars respecting this discovery have yet reached this country. We do not even know whether the report be well founded.

#### V. Supposed New Metal in Manganese.

DR JOHN of Berlin announced the discovery of a new volatile and acidifiable metal in the grey ore of manganese from Saxony. He obtained it by distilling the ore with sulphuric acid. The volatile metallic acid combines with a weak solution of potash put into the receiver, and tinges it crimson. The infusion of galls throws down a chesnut brown precipitate from this liquor. The prussiates change the red colour to a fine lemon yellow, but produce no precipitate. When the liquor is heated with a little alcohol, it becomes green, and the alkaline carbonates throw down from it a brown coloured oxide; but they do not precipitate the liquid till it has been thus altered by alcohol ‡. Berzelius informs us that he was acquainted with this supposed new metallic substance as early as 1800, and

\* *Ann. de Chim.* lxxi. 103.

† *Jour. de Phys.* lxxvii. 71.

‡ Nicholson's *Jour.* xxiii. 159.



He has shown that it depends upon the softness of the metal, which makes it escape from pressure. He found that when it was confined in such a manner that it could not make its escape, its specific gravity increased like that of other ductile metals. A piece of lead, thus treated, increased in specific gravity from 11.358 to 11.388.

#### VII. Oxidizement of Metals.

MORVEAU has published an experiment, showing that gold may be oxidized by electricity, in an imperfect vacuum of an air-pump; but that when the vacuum is complete, no oxidizement takes place. This is very likely; and it destroys the supposed anomaly of the oxidizement of metals in vacuo by electricity \*.

Gay Lussac, in a paper published in the second volume of the *Memoires d'Arcueil* †, has endeavoured to prove, that the quantity of acid which combines with a metallic oxide, is always proportional to the quantity of oxygen which it contains. The protoxide of mercury consists of 100 metal united to 5 oxygen, the peroxide of 100 metal united to 10 oxygen; of course, according to this theory, the peroxide requires twice as much acid to saturate it as the protoxide. There can be little doubt that Gay Lussac was led to the notion of this law from the *atomic theory* of Dalton, which I have explained at great length under the article *affinity*, in the third volume of this work. He

\* *Ann. de Chim.* lxi. 261.

† P. 159.



Book I.  
Division L.

has drawn his conclusions from the well known phenomena which take place when one metal precipitates another. When zinc is used to precipitate lead from the acetate, the acetate of zinc formed is just as neutral as the acetate of lead was. Suppose 100 grains of lead in the salt. The oxygen in such a quantity of lead may be rated at 8 grains. But 100 grains of zinc require 25 of oxygen to convert them into zinc oxide. Hence it is obvious, that the whole oxygen the lead will only oxidize 32 grains of zinc. As the acid is neutralized, it follows that 32 grains of zinc, combined with 8 of oxygen, are capable of neutralizing as much acetic acid, as 100 grains of lead combined with 8 of oxygen. Various other examples are brought by Mr Gay Lussac, all of a similar nature. If this law hold universally, as is extremely likely, though it would require a much more complete indication of particulars to prove it in a satisfactory manner, it will be of great importance, by enabling us to determine the composition of metallic salts, from the knowledge of the quantity of oxygen with which a metal combines, and the exact analysis of a single salt is of great genus. Or, knowing the composition of the salts, it will enable us to determine the proportion of oxygen with which the different metals unite.

#### VIII. Metallic Hydrogurets.

It is probable that hydrogen gas is capable of dissolving a considerable number of the metals. Arsenical hydrogen gas is almost the only one of these combinations at present known. But Mr Davy has lately discovered two new ones, *tellureted* and *potassureted*

*hydrogen*, consisting, as their names import, of hydrogen gas, holding in solution tellurium and potassium. He has also discovered *borureted hydrogen*, a gas consisting of hydrogen holding boracium in solution. All of these gases contain their own bulk of hydrogen gas. Tellureted hydrogen is a weak acid, similar to sulphureted hydrogen.

Chap. IV.

## IX. Metallic Phosphurets.

GROTHUS has shown, that a solution of phosphorus in alcohol precipitates gold, silver, mercury, and copper, from their solutions in the state of phosphurets. If two parts of phosphorus, and one part of potash and soda, be heated in six parts of alcohol, a liquid is formed, which precipitates nitrate of lead orange, and muriate of antimony brown. These precipitates consist of phosphureted oxide of lead, and phosphureted oxide of antimony. During the heating of the phosphorus and alkali in the alcohol, a gas comes over which is inflammable, and which is a compound of phosphorus, carbon, and hydrogen. 100 measures of it require for combustion 72 measures of oxygen gas; the products are water, phosphoric acid, and carbonic acid\*.

## X. Tantalum and Columbium.

I OMITTED the account of *tantalum* (the metal discovered by Ekeberg), because it was announced by the discoverer of it, that he had ascertained it to be a com-

---

\* *Ann. de Chim.* lxi. 17.

Book II.  
Division II.

pound of known substances. This is probably incorrect. But Dr Wollaston has lately shown, by a very ingenious set of experiments, that it is the same with *columbium*, the metal previously discovered by Mr Hatchett. Colombite and tantalite, the ores from which the respective metals were obtained, were found composed of the same constituents, a white oxide, iron, and manganese. The white oxide from both possessed the same properties. It is nearly insoluble in sulphuric, nitric, and muriatic acids; but is easily dissolved by oxalic, tartaric, and citric acids, provided it be used upon before it is dry. It is rendered soluble in water, by fusing it with potash or its carbonate. Soda may be employed, but a much greater quantity of it is necessary. Neither prussiate of potash, nor hydrophuret of potash, occasion any precipitate in solution of this white powder; but it is thrown down orange by the infusions of galls, provided there be no copper either of acid or alkali present\*.

BOOK I.—DIVISION II.—CHAP. II. OF CALORIC.—  
SECT. III. Percussion. Vol. I. p. 611.

BERTHOLLET, Pictet, and Biot, have lately made a set of experiments, to ascertain the quantity of heat evolved when ductile metals are suddenly struck forcibly, as when they are stamped in the process of coining. The experiments were made upon pieces of gold, silver, and copper, of the same size and shape,

---

\* Nicholson's Jour. xiv. 23.



and care was taken that all the parts of the apparatus had acquired the same temperature before the experiments began. Copper evolved most heat, silver was next in order, and gold evolved the least. The first blow evolved the most heat, and it diminished gradually, and after the third blow was hardly perceptible. The heat acquired was estimated by throwing the piece of metal struck into a quantity of water, and ascertaining the change of temperature which the water underwent. The following table exhibits the increase of temperature, experienced by two pieces of copper by three successive blows;

1st Blow	{ 1st Piece .....	17.44°
	{ 2d Piece .....	20.80
2d Blow	{ 1st Piece .....	7.30
	{ 2d Piece .....	3.69
3d Blow	{ 1st Piece .....	1.90
	{ 2d Piece .....	1.46

The whole quantity of heat evolved by each of these pieces of copper is nearly the same; that from the first piece being 26.64°, and that from the second 25.95°.

The following table exhibits the heat evolved from two pieces of silver treated in the same way.

1st Blow	{ 1st Piece .....	6.19°
	{ 2d Piece .....	7.30
2d Blow	{ 1st Piece .....	5.85
	{ 2d Piece .....	2.14
3d Blow	{ 1st Piece .....	2.76
	{ 2d Piece .....	2.02
Total evolved from the 1st piece		14.74
Ditto from the 2d .....		11.46



Book II.  
Division I.

The change in specific gravity which the metal underwent, was found to be proportional to the heat thus evolved, as appears from the following table, deduced from their experiments. The specific gravities were taken at the temperature of  $40^{\circ}5^{\circ}$ .

Specific gravity of gold .....	19'2351
Ditto annealed .....	19'2290
Ditto struck .....	19'2487
Specific gravity of silver .....	10'4667
Ditto annealed .....	10'4465
Ditto struck .....	10'4833
Specific gravity of copper .....	8'8529
Ditto struck .....	8'8625
Ditto struck a second time .....	8'9261

From these experiments it is obvious, that the heat evolved when metals are struck is owing to the condensation, and proportional to the condensation. Hence, when they can no longer be condensed, they cease to evolve heat. These philosophers observed, during their experiments, that heat or cold is propagated much more rapidly, from one piece of metal to another, when they are struck, than when they are simply placed in contact\*.

#### BOOK II.—DIVISION I.—CHAP. I. AMMONIA.

Vol. II. p. 5.

A GREAT many experiments have been lately made on ammonia, some of them of a very extraordinary

---

\* *Mem. d'Arcueil*, ii. p. 441.

re, and still very obscure; but they are highly deserving of attention, as they promise, when followed out the farther, to throw a new and unexpected light on the constituents of bodies, and some of the most complicated natural phenomena.

No less than four new analyses of ammoniacal have been made, in consequence of the experiments of Davy, to show that oxygen is one of its constituents. The first by Berthollet junior, the second by Lussac, the third by Mr Davy, and the fourth by Henry. Mr Davy had suspected the presence of oxygen as one of the constituents of ammoniacal gas, and had made some experiments which appeared to render his suspicions probable. These experiments I have related under the article ammonia. The object of the new analysis was to determine how far this opinion of Davy was correct.

The experiments of Mr Berthollet junior were made with every possible precaution to ensure precision. He did not detect the presence of oxygen; nor was there any notable quantity of water formed when great quantities of the ammoniacal gas were decomposed by a red heat. When 1 of the gas is decomposed by electricity, the bulk is increased to 2.04643. This expanded gas was found composed, by bulk, of 755 parts of hydrogen, 245 of azotic gas, equivalent to 300 of hydrogen, 97.35 of azote. Converting these measures into weights, according to the specific gravity of the different gases found by Biot and Arrago\*, Mr Berthollet has

Berthollet's  
analysis.

---

\* They found the specific gravity of azotic gas 0.96913; that of hydrogen 0.07321; that of ammoniacal 0.59669; that of air being 1.000.

Book II.  
Division I.

concluded, from his experiments, that ammonia contains no oxygen, and that it is composed, by weight, of

81.13 azote

18.87 hydrogen

---

100.00 \*

The result of the experiments of Gay Lussac (if indeed his result is not drawn rather from theory) is, that ammonia is composed of 75 parts, by bulk, of hydrogen, and 25 of azote, or 300 hydrogen and 100 azote. Hence, from the specific gravity of the gases, as ascertained by Biot and Arrago, he deduces ammonia as composed, by weight, of

81.525 azote

18.475 hydrogen

---

100.000 †

Henry's  
analysis.

Dr Henry found that the expansion of ammoniacal gas by electricity, was very much influenced by its state of dryness or moisture. When the gas had been dried by means of potash, when the mercury, over which it stood, had been recently boiled in the tube, and when every precaution was taken to exclude moisture, then 100 parts of the gas expanded by electricity to 180. But when these precautions were not taken, he found the bulk of the gas often doubled by electricity. This difference he explains in a satisfactory manner. If any moisture adhere to the mercury or tube, it absorbs a portion of the ammoniacal gas; this portion is evolved during the process, so that the real quantity of ammo-

---

\* *Mem. d'Arrago*, ii. 262.

† *Ibid.* p. 253.



niacal gas experimented on is greater than appears. No traces of the presence of oxygen, as a constituent of ammonia, could be perceived. The expanded gas he found a mixture of 74 measures of hydrogen gas and 26 of azotic. Now, if we take the specific gravity of azotic gas at 0.978, of hydrogen gas at 0.084, and of ammoniacal gas at 0.602; and suppose, as has been ascertained by the experiments of Sir George Shuckburgh, that at the temperature of 60°, and under the pressure of 30 inches of mercury, 100 cubic inches of common air weigh 30.5 grains; then we have 100 cubic inches of ammonia weighing 18.361 grains. These are expanded by electricity into 133.2 cubic inches of hydrogen gas, and 46.8 of azotic gas.

Now 133.2 inches of hydrogen weigh 3.413 grains

46.8 ..... azotic ..... 13.960

---

Weight of the gas evolved ..... 17.373

Weight of the ammonia ..... 18.361

---

0.988

Thus it appears that the weight of the ammonia exceeds that of the gases nearly one grain, or about  $\frac{1}{10}$ th of the whole. This error, it must be acknowledged, is not great. But it is sufficient to show us that absolute precision has not yet been attained in estimating the proportion of the constituents of ammonia. The most probable source of error is in the specific gravities of the different gases. If we take the specific gravities of these different gases, as ascertained by Biot and Arrago, and given in a preceding note, the difference will amount to almost 1.4 grain. According to this analysis of Henry, ammonia is composed, by weight, of



Book II.  
Division I.

80.36 azote  
19.64 hydrogen  

---

100.00

Ammonia  
detonates  
with oxy-  
gen,

Dr Henry has pointed out three other modes of analysing ammoniacal gas, all of which corroborate the preceding result.

The first method is detonating a mixture of ammoniacal gas and oxygen gas by the electric spark. This method was tried by Berthollet junior, but he was not satisfied with the results\*. Dr Henry has pointed out the sources of error, and shown how to avoid them. The mixture burns in all proportions between 3 oxygen and 1 ammonia, and 3 ammonia and 1.4 oxygen, by bulk. When the oxygen exceeds the ammonia (as when it is double or upwards), the whole ammonia disappears, and a quantity of nitrate of ammonia is deposited. This prevents the accuracy of the experiments by withdrawing a portion of the azote. When the ammonia exceeds (when it is double the oxygen, for example), the whole of the ammonia is decomposed by the explosion; part of its hydrogen unites with the oxygen, the rest remains mixed with the azote, and may be detonated by a second addition of oxygen. By this method the whole hydrogen may be separated, and its quantity determined. The residual gas (the oxygen being absorbed) gives the azote. It appears from Dr Henry's experiments, that 100 measures of dry ammoniacal gas, when thus treated, require, for complete saturation, 87.5 measures of oxygen. Hence it follows that the hydrogen, in 100 mea-

\* *Mém. d'Arcueil*, ii. 224.

tures of ammonia, is equivalent to 135 measures, which differs a little from the quantity deduced by the same philosopher from his electrical experiments.

Chap. I.

The second method is to detonate a mixture of ammoniacal and nitrous oxide gases. This mixture burns in any proportion between 1 ammonia and 5 nitrous oxide, and 2 ammonia and 1 nitrous oxide. When the nitrous oxide greatly exceeds, there is no diminution of bulk after firing, and the residue consists of a mixture of nitrous oxide, oxygen, and azote. When the ammonia is redundant, there is a little diminution of bulk after firing, and the residue consists of a mixture of hydrogen and azote, with occasionally a little undecomposed ammonia. 100 measures of ammonia require, for saturation, 130 measures of nitrous gas.

Nitrous oxide.

The third method is to detonate a mixture of ammonia and nitrous gas; for, although this gas cannot be fired with hydrogen or the heavy inflammable gases, it may with ammonia. 100 measures of ammonia require about 120 measures of nitrous gas\*.

And nitrous gas.

Mr Davy's late experiments coincide exactly with those of Dr Henry, and give as a result, that ammonia is composed of 74 measures, by bulk, of hydrogen gas, and 26 of azotic gas. It is not necessary therefore to enter into details.

Composed of hydrogen and azote.

By the experiments just related, it seems fully established that ammonia is composed simply of hydrogen and azote, and that oxygen does not enter as a constituent. On the other hand, it seems to follow, from the curious amalgam obtained from ammonia by the gal-

\* Henry's Experiments on Ammonia Phil. Trans. 1809.

Book. II.  
Division I.

vanic energy, as related under the article *ammonia*, that oxygen is really a constituent of ammonia. This leads to the conclusion, that either hydrogen or azote is a compound, and that oxygen is one of its constituents.

The experiments of Berthollet junior, respecting the expansion of ammoniacal gas by electricity, do not agree with those of Davy and Henry. From the great precautions taken by the British chemists, we have reason to confide in the results which they obtained. As to the proportional measures of the two gases obtained, all the experimenters very nearly agree, as will appear from the following Table :

	Hydrogen.	Azote.
Berthollet .....	75.5 .....	24.5
Davy .....	74.0 .....	26.0
Henry .....	73.75.....	26.25
Mean	74.42	25.58

This differs but little from the proportions of Gay Lussac, namely 75 measures of hydrogen and 25 of azote ; numbers which, on account of their proportions to each other, are exceedingly convenient. If we were accurately acquainted with the specific gravity of hydrogen and azote, it would be easy to determine the exact composition of ammonia with almost perfect accuracy.

Action of  
potassium  
on ammo-  
nia.

2. When potassium is heated in contact with dry ammoniacal gas, it is changed into an olive coloured matter ; a great quantity of the ammoniacal gas is absorbed, and a quantity of hydrogen gas is evolved. According to Messrs Gay Lussac and Thenard, the hydrogen gas evolved amounts to about  $\frac{1}{3}$ ds of the bulk of the ammoniacal gas absorbed. When the olive coloured



matter is heated, about  $\frac{2}{3}$ ths of the ammonia absorbed is obtained;  $\frac{2}{3}$ ths in the state of ammonia, and  $\frac{1}{3}$ th in the elements of that compound. If a few drops of water be brought in contact with the olive coloured matter thus heated, the other  $\frac{2}{3}$ ths of the ammonia absorbed are discharged, while at the same time the potassium is changed into potash. Thus, according to these chemists, the whole of the ammonia absorbed may be recovered. By the process the potassium is converted into potash and hydrogen. Hence they have concluded that potassium is not a simple substance, and the base of potash, but in reality a compound of potash and hydrogen\*.

Chap. I.

The experiments of Mr Davy on this subject, made with every precaution, and multiplied and varied in every possible way, do not agree with those of the French chemists, and destroy the consequences which they have drawn respecting the composition of potassium; but they lead to others, if possible, still more extraordinary.

When ammonia is brought into contact with about twice its weight of potassium, at the temperature of the atmosphere, the metal loses its lustre and becomes white; there is a slight diminution in the volume of the gas, but no other effects are produced. The white crust formed is potash, and the ammonia is found mixed with a quantity of hydrogen, about equal to the bulk of the metal. On heating the potassium the colour of the crust changes from white to bright azure, and passes through shades of blue and green to dark olive. There is a considerable effervescence; the metal be-

Hydrogen  
emitted.



Book II.  
Division I.

comes porous, and appears crystallized, and at last is wholly converted into an olive coloured matter. Ammoniacal gas is absorbed, and hydrogen gas evolved. The proportion of ammonia absorbed varies according to its state of dryness; the absorption being the greater the drier the gas is. Thus 8 grains of potassium, when heated in contact with ammonia saturated with moisture, absorbed  $12\frac{1}{4}$  cubic inches of ammonia; but when the ammonia was as dry as possible, 16 cubic inches were absorbed. The hydrogen gas evolved depends upon the quantity of potassium. It is always a very little less than the quantity of hydrogen, which the same quantity of potassium would generate when brought in contact with water. Thus 8 grains of potassium, by their action on water, produced 8.5 cubic inches of hydrogen gas, while, by their action on ammonia,  $8\frac{1}{4}$  cubic inches were evolved.

Olive coloured matter.

The olive coloured matter, into which the potassium is converted, possesses the following properties: It is crystallized, and presents irregular facets, which are very dark, and in colour and lustre not unlike protoxide of iron. It is opaque in large masses, but semi-transparent in thin films, and appears brown by transmitted light. It melts at a little above the temperature of  $212^{\circ}$ ; and if the heat be increased, gives out bubbles of gas. It is considerably heavier than water. It is a non-conductor of electricity. When melted in oxygen gas it burns with great brilliancy; oxygen is absorbed, azote emitted, and potash formed. When brought in contact with water it produces heat, and often inflammation, and evolves ammonia. When plunged into water it disappears with effervescence, and hydrogen gas is evolved. It rapidly effervesces and deli-

quiesces in air, but may be preserved under naphtha, in which, however, it gradually softens, and seems partially to dissolve.

Chap. I.

Potassium, when converted into this olive coloured matter, increases in weight; and it, together with the hydrogen evolved, is equal to the weight of the whole potassium employed, and of the ammonia absorbed.

When the olive coloured substance is gradually heated it melts, effervesces, and gives off a considerable quantity of elastic fluid, and at last, in a red heat, is converted into a dull grey solid, which undergoes no farther alteration at that temperature. The olive coloured matter from 8 grains of potassium, by this process, gave out 13.75 cubic inches of gas. These consisted of

Action of  
heat on it. ]

1.00 ammonia
9.11 hydrogen gas
3.64 azotic gas

---

13.75

We may observe here, that more than one half of the ammonia has disappeared in this experiment. The quantity absorbed (deducting the cubic inch evolved) may be stated at 15 cubic inches, which weigh 2.754 grains. But the whole weight of the hydrogen and azotic gas evolved does not exceed 1.327 grain.

The quantity of ammonia evolved from the olive coloured substance depends upon the application of moisture; and it appears likely, from Mr Davy's experiments, that if moisture were applied only in the requisite proportion, the ammonia evolved would be just equal to what had been absorbed in the first part of the process. In one experiment, in which 13 cubic inches of ammonia had been absorbed, by heating the olive

Book II.  
Division I.

coloured substance, in contact with potash containing its water of crystallization, nearly 11.75 cubic inches of ammonia were evolved. It appears probable, likewise, that when no moisture whatever is present, no ammonia is given out.

The substance that remains, after the olive coloured matter has thus been exposed to a red heat, possesses the following properties. Its colour is black, and its lustre not much inferior to that of plumbago. It is opaque, very brittle, and gives a deep grey powder. It is a conductor of electricity. It does not melt at a low red heat, but blackens glass at that temperature, and a greyish sublimate rises from it, which likewise blackens glass. When exposed to the air, it burns spontaneously with a deep red light. With water it effervesces, evolving ammonia, and leaving nothing but potash. A little hydrogen is also evolved. It does not act on mercury, but combines with sulphur and phosphorus by heat; the compounds are highly inflammable, and emit ammonia, and phosphureted and sulphureted hydrogen gas, respectively, by the action of water.

A deficiency of azote.

This residuary matter ought to be a compound of potassium, azote, and a little oxygen. For most of the hydrogen in the ammonia has been evolved; 15 cubic inches of ammonia would have evolved about 20 cubic inches of hydrogen, and there were obtained above 17 inches. But little more than half the azote has been evolved; 15 cubic inches of ammonia ought to give out nearly 7 inches of azotic gas, whereas only 3.64 were obtained. When the residue was burnt in oxygen gas, potash was formed, and azotic gas given out; but the quantity was much smaller than it ought



to be. When the residue was violently heated in a tube of platinum or iron, one portion of it was converted into potash, another portion became pure potassium, and an elastic fluid was given out, consisting chiefly of hydrogen mixed with a little azote. Thus it appears, that, by these processes, a greater quantity of hydrogen, and a smaller quantity of azote was obtained, than ammonia yields when decomposed by electricity; while a portion of the potassium was converted into potash, and of course had combined with oxygen. The obvious inference from these experiments is, that a portion of the azote had been decomposed, and that its constituents are hydrogen and oxygen; the first separated in the form of gas, the last united with the potassium. But the subject requires a much more complete investigation, before consequences of so much importance can be deduced. Mr Davy is at present engaged in the investigation; and it is to be hoped, that his experiments will elucidate this most important, but very obscure department of chemistry.

CHAP. II. FIXED ALKALIES. Vol. II. p. 22.

FROM the experiments of Mr D'Arcet, it appears, that potash or soda, prepared by means of alcohol, and exposed for some time to a red heat, still retain about 27 *per cent.* of water, which can only be separated by combining the alkali with an acid\*. This corresponds nearly with the estimate of Curaudau, who found that

---

\* *Ann. de Chim.* lxxviii. 175.



Book II.  
Division I.

New method of  
procuring  
potassium.

potash, prepared by means of alcohol, still retained 27.5 *per cent.* of water \*. Berthollet had convinced himself, that at least 13 *per cent.* of water adhered to the alkali, and could not be separated by heat †.

Curaudan has pointed out a new method of procuring potassium and sodium. It consists in mixing the alkaline subcarbonates with charcoal and a little oil, and gradually raising them to a white heat in iron tubes or earthen-ware retorts. The metallic substances are generated and volatilized. By exposing cold iron rods to the fumes, they condense, and may be separated by plunging the rod into naphtha or oil of turpentine. This method is of importance, by proving that charcoal is capable of decomposing the alkalies; but the quantity of metal that can be collected by this process must be small ‡.

Several additions have been made to our knowledge of the properties of potassium and sodium, by the experiments of Gay Lussac and Thenard; their results do not always agree with those of Mr Davy, though in general they do. Their potassium was obtained by decomposing potash, by means of iron turnings, in the experiment with the gun-barrel. It was heavier than Mr Davy's, being of the specific gravity 0.874, owing probably to its containing some iron: but, in other respects, its properties corresponded. It appears, from Mr Davy's experiments, that a grain of potassium, when brought in contact with water, gives out  $1\frac{1}{2}$ , = 1.0625, cubic inches of hydrogen gas, at the temperature of

Hydrogen  
evolved by  
potassium.

\* *Jour. de Phys.* lxxii. 9.

† *Ann. Mr Chim.* lxxviii. 184.

‡ *Nicholson's Jour.* xxiv. 37.

60°, and under a pressure of 30 inches of mercury. Chap. II.  
 By the experiments of Thenard and Gay Lussac, the hydrogen given out by 1 grain of potassium, acting on water, under the same pressure and at the same temperature, amounts to 1'1591 cubic inch\*.

According to the French chemists, potassium absorbs a great quantity of hydrogen gas, and assumes a greyish white colour. Abundance of hydrogen may be expelled by the action of heat. Mr Davy's account is different. He found that hydrogen has the property of dissolving a considerable quantity of potassium, and of forming a gas, to which he gives the name of potassureted hydrogen. It takes fire when it comes in contact with the air.

Thenard and Gay Lussac tried the effect of potassium upon various metallic oxides and salts in a dry state. Their method was to put a piece of potassium, of the size of a pea, into a glass tube, and to cover it with about ten times the bulk of the substance to be tried. The tube was then exposed to a heat sufficient to melt the potassium. All the substances tried were decomposed, and in many cases combustion took place. The following is a summary of their experiments.

1. Sulphate of barytes. Decomposed, but without inflammation.
2. Sulphate of barytes. Brilliant inflammation.
3. Sulphate of lime. Slight inflammation.
4. Sulphate of lead. Brilliant inflammation.
5. Sulphate of mercury. Inflammation.

Action of  
potassium  
on salts.

---

\* *Mem. d'Arcueil*, ii. 302.

32. Grey oxide of nickel. Brilliant inflammation. 1 Chap. II.  
 33. Green oxide of chromium. No inflammation. A  
     black substance produced, which takes fire in  
     the open air.  
 34. Sulphuric, nitric, and liquid muriatic acids, Splen-  
     did inflammation \*.

Messrs Thenard and Gay Lussac have endeavoured to prove, that potassium and sodium are not the bases of the fixed alkalies, but compounds of the fixed alkalies and hydrogen. This hypothesis has been very generally embraced both in France and Germany. It is not, however, consistent with the phenomena, and has been victoriously refuted by Mr Davy. The most plausible argument urged in defence of it is, the low specific gravity of potassium and sodium, considerably inferior to that of potash or soda. Now, no instance is known of a metallic oxide specifically heavier than the metal which constitutes its base. This objection is only apparent. What we call potash and soda, at present, are only the hydrates of these bodies. We are entirely ignorant of the specific gravity of the pure alkalies. Their union with water is intimate; of course, the condensation of the water is great. For any thing we know to the contrary, the hydrates may be much heavier than the pure alkalies.

Nature of  
potassium.

---

\* *Mém. d'Arcueil*, ii. 334.



Book II.  
Division II.

BOOK II.—DIVISION II.—CHAP. II. ACIDS.  
Vol. II. p. 169.

A VARIETY of interesting additions to the history of the acids have been made. Of these I now proceed to give an account.

I. Fluoric Acid.

ALL attempts to procure fluoric acid in a state of complete purity have failed. In its usual state, when obtained by means of fluat of lime and sulphuric acid in glass vessels, it holds, as is well known, silica in solution.

Thenard and Gay Lussac endeavoured to procure it pure, by calcining in an iron tube a mixture of fluat of lime and vitreous boracic acid. An acid gas is procured in abundance. When mixed with air or any other gas, except the oxymuriatic acid, it produces dense white fumes, unless the gases have been previously artificially dried. Water absorbs this gas in great quantities, and when saturated with it is limpid, smoky, and very caustic. By heat, about one fifth part of the gas is expelled, but no degree of heat is capable of driving off more. The liquid then assumes the appearance of sulphuric acid; it is equally caustic, does not boil till heated considerably above the boiling point of water, and when distilled over, condenses like that acid. It acts like sulphuric acid on vegetable substances, charring them, and forming a quantity of water. With alcohol it forms a peculiar ether. This remarkable acid, which does not act on glass, is a combina-

Fluoboric  
acid.



tion of fluoric and boracic acids. Thenard and Gay Lussac have given it the name of *fluo-boric* gas\*. Chap. II.

When fluat of lime and sulphuric acid are heated in leaden vessels, no gas is obtained, but only an acid liquid, consisting of water and fluoric acid combined together. When exposed to the air it emits vapours. When mixed with water it heats, and even enters into ebullition. When brought in contact with glass, it acts upon it, becomes hot, and is converted into siliciferous fluoric acid gas. When allowed to touch the skin, a white spot is formed, with the pain of a burn, which terminates in a blister. The best remedy is to touch the place with a weak solution of potash. When brought in contact with potassium, a violent combustion takes place, hydrogen is evolved, and fluat of potash and water disengaged†.

Liquid fluoric acid.

When potassium is placed in contact with fluoric acid gas, holding silica in solution, white fumes appear, the metal loses its splendour, is covered with a white crust, and some hydrogen gas is evolved. When heat is applied, the metal bursts through the crust, becomes first of a copper colour, then bluish black, and at last inflames and burns with a most brilliant red light. The whole, or a part of the fluoric acid gas disappears, according to the portion of potassium present; a chocolate coloured mass remains in the bottom of the retort, and a sublimate, in some parts chocolate, in others yellow, is found round the sides and at the top of the retort. When the fluoric acid gas has been

Action of potassium on fluoric acid.

\* *Mém. d'Arcueil*, ii. 317.

† *Ibid.* ii. 323.

Book II.  
Division II.

dried, the residual gas amounts to about  $\frac{1}{3}$ th of the fluoric acid gas destroyed; when the gas has not been dried, it amounts to about  $\frac{1}{2}$ th part. Hence, probably, it is owing to the decomposition of water, for it possesses the properties of hydrogen.

The chocolate coloured matter formed, when examined with the magnifier, appears to consist of different substances mixed together; a blackish matter, a white apparently saline matter, and a substance having different shades of brown and fawn. It is a non-conductor of electricity. When thrown into water, it effervesces strongly, and an inflammable gas is evolved, having some resemblance in smell to phosphureted hydrogen gas. When heated in the open air, it burns, and is converted into a white saline mass\*. There can be little doubt that the fluoric acid gas is decomposed during this combustion, and that its basis exists in the chocolate coloured residuum; but, as it appears to form a compound with the potash formed, it has not been possible hitherto to ascertain its properties. In this respect fluoric acid resembles sulphuric and phosphoric acids, which are decomposed by potassium, but their bases combine with the potash formed.

## II. Boracic Acid.

I HAVE given, in page 773 of this Appendix, an account of the composition of this acid, and of the properties of its basis, to which the name of *boracium*

---

\* Davy, *Phil. Trans.* 1809.

has been given. It appears to be a compound of two parts oxygen, and one part of boracium. Chap. II.

### III. Oxymuriatic Acid.

THE recent experiments of Thenard and Gay Lussac, related in a preceding part of this Appendix, alter our notions respecting this acid. Instead of the oxygen being loosely combined, it appears to be united most firmly to the muriatic acid, and not to be capable of being separated, even by the action of carbon at a red heat. The easy decomposition of this acid, in common cases, is owing to the strong affinity of muriatic acid for water.

Majon has observed, that when bottles filled with oxymuriatic acid gas are exposed to the sun, the colour and smell disappears, and a smell is observed similar to that of muriatic ether. Hence he suspects that ether is formed during the decomposition of this acid by light. But his experiments are altogether insufficient to prove the truth of this opinion \*.

### IV. Chromic Acid and Chromates.

Vauquelin has recently published an important paper on the method of procuring chromic acid and oxide of chrome, and on the combination of these bodies with bases and acids †.

It is from chromate of iron that these substances are usually procured, because that is by far the most abun-

---

\* *Ann. de Chim.* lxx. 264.

† *Ann. de Chim.* lxx. 70.

Book II.  
Division II.

dant ore of that metal. Two parts of this substance are mixed with one part of nitre, and calcined for some time in a crucible. The mass is digested in water, the liquid separated, and the residue treated with muriatic acid. The acid solution is speedily decanted off, and the residue, which is chromate of iron undecomposed, is to be calcined a second time with the fourth part of its weight of nitre, and treated as before. When the ore is completely decomposed, the aqueous solutions, which contain the oxide of chromium, are to be collected, saturated with nitric acid, and crystallized, in order to separate some impurities. The salt is then to be dissolved in water, and mixed with a solution of nitrate of mercury, containing as little excess of acid as possible. A red precipitate falls, consisting of the chromic acid combined with the mercury. It is to be thoroughly washed, and exposed to heat in a stone-ware retort. The oxide of chromium remains in a state of purity.

How to obtain chromic acid.

Chromic acid may be obtained pure by mixing chromate of potash with nitrate of barytes. The precipitate, which consists of chromate of barytes, is to be well washed, and exactly decomposed by means of sulphuric acid, not added in excess. The sulphate of barytes being separated, the liquid is to be cautiously evaporated to dryness, water added, and the process repeated two or three times, in order to get rid of the nitric acid.

Oxides of chromium.

The oxide of chromium is green, the chromic acid red. 100 parts of oxide of chromium are converted into chromic acid by combining with 16.6 parts of oxygen. Chromic acid is decomposed by sulphurous acid, and converted into oxide of chromium. The colour is



at first reddish brown, but by heat it is converted into green. Chap. II.

Oxide of chromium, obtained by calcining chromate of mercury, is soluble in acids with great difficulty; but the oxide of chromium, obtained by decomposing chromate of potash by sulphureted hydrogen, filtrating and adding a little potash, is easily soluble in the different acids.

The sulphate of chromium is easily decomposed by heat. Salts of chromium. Muriate of chromium, evaporated to dryness, leaves a red powder, which deliquesces in the air. The solution is green. When heated oxymuriatic acid gas is given out, it swells up, and is converted into yellow plates, and at last nothing remains but green oxide. Nitric acid dissolves oxide of chromium with facility, and without altering its nature; but if the solution be evaporated to dryness, a portion of the oxide is converted into acid. Phosphate of chromium has an emerald green colour, oxalate of chromium is of an amethyst red. Sulphurous acid readily dissolves the oxide of chromium. Oxide of chromium, recently precipitated, is soluble in caustic potash; the solution has a fine green colour.

Chromate of potash.—There are two varieties of this salt: 1. The neutral chromate, of a lemon yellow colour, which crystallizes in small prisms. When heated it becomes red, but assumes its natural colour on cooling. 2. The superchromate, which has an orange yellow colour, and crystallizes in fine prisms. Chromate of potash.

Chromate of ammonia.—When chromic acid is saturated with ammonia, and the liquid set aside, a salt gradually forms of a fine yellow colour. It is decomposed by a slight heat, even when in solution, brown. Chromate of ammonia.

Book II.  
Division II.Chromate  
of barytes.

flocks of chromic acid precipitating, which become green when calcined.

Chromate of barytes.—This salt is easily formed by mixing chromate of potash and nitrate of barytes. The salt precipitates in powder. It is not sensibly soluble in water, and is composed of

40.16 chromic acid

59.84 barytes

---

100.00

Chromate  
of lime.

Chromate of lime.—This salt is pretty soluble in water. By evaporation it yields silky plates of a yellowish brown colour, readily soluble in water. The fixed alkalies decompose it.

Chromate  
of magnesia.

Chromate of magnesia.—This salt is very soluble in water. It crystallizes in transparent six-sided prisms, of a fine topaz yellow colour. When in large masses its colour is orange yellow. The magnesia is precipitated by the caustic fixed alkalies, and the alkaline earths.

Chromate  
of iron.

Chromate of iron.—When chromate of potash is dropt into sulphate of iron, a fawn coloured precipitate falls, which contains oxide of chromium. Hence it appears that the black oxide of iron decomposes chromic acid. To compose chromate of iron, then, we must employ oxysulphate of iron.

Chromate  
of lead.

Chromate of lead.—This salt assumes different shades of colour according to the method of preparing it. Neutral chromate of potash throws it down of an orange yellow, superchromate of a deep lemon yellow, subchromate of a yellowish red or deep red. The chromate of lead, made by means of a solution slightly acid,

has the colour which is most sought after by painters, Chap. II.  
and which in reality is the most solid.

Chromate of copper.—This salt may be formed by mixing together solutions of chromate of potash and sulphate of copper. A precipitate falls, which is at first yellowish brown, but becomes bistre brown when dried.

Chromate of silver.—This salt may be formed by mixing chromate of potash and nitrate of silver. The precipitate is reddish brown when the liquids are mixed hot, purple red when they are mixed cold, and carmine red when the chromate of potash contains an excess of acid. It becomes brown when exposed to the light, and is soluble in nitric acid.

Oxide of chromium is employed to colour porcelain. It gives a fine green, and resists a strong heat, better than most other metallic colours. An enamel is made of it, which, when applied to copper or silver, imitates very exactly the colour of gold\*.

#### V. Acetic Acid.

FROM recent experiments, as well as others made long ago, it appears that the specific gravity of acetic acid does not indicate its strength. Thus Mollerat found two specimens of acid of the same specific gravity, Specific gravity. namely 1.0630; though the first contained 0.87125 of acid, and the other only 0.41275. When water is added to the strongest acid, its specific gravity increases till it amounts to 1.0791. The acid then contains 0.67256 of its weight of acid. If more water be added,

---

\* *Ann. de Chim.* lxx. 70.



Book II.  
Division II.

the specific gravity gradually diminishes. Thus it appears that the specific gravity of acetic acid increases with its strength till it reaches 1.0791, when the proportion of acid amounts to 0.07256. The specific gravity after this diminishes as the strength increases\*.

These changes in the specific gravity are sometimes occasioned by the presence of a peculiar spiritous liquor in strong acetic acid. This liquor being lighter than water, balances the specific gravity of the acid, and thus causes the mixture to be specifically lighter, even when the quantity of acid is increased. We are indebted to Mr Chenevix for an important set of experiments on the formation and properties of this peculiar spiritous liquor, to which he has given the name of *pyro-acetic spirit* †. The following is a summary of the most important parts of these experiments.

English vinegar, of the specific gravity 1.0042, was found to contain, besides water and acetic acid, a peculiar vegetable matter, which may be distilled over with the liquid, and which has been sometimes called *mucilage*, sometimes *extractive*. It contains also traces of a spiritous liquor. French vinegar was found to contain the same substances, but their proportion was different. Its specific gravity was 1.0072, and it contained more acetic acid and spiritous liquor, and less mucilage, than English vinegar.

Distillation  
of metalline  
acetates.

When the metalline and alkaline or earthy acetates are distilled, acetic acid, mixed with water, and this pyro-acetic spirit, is obtained. The metallic base, mixed with charcoal, remains in the retort; and there flies off

\* Mollerat, *Ann. de Chim.* lxxviii. 82.

† Ibid. lxx. 6.



a mixture of carbonic acid and heavy inflammable gas. The metallic base is usually reduced to the metallic state; and the more difficult this reduction is, the greater is the quantity of pyro-acetic spirit formed. The following Table exhibits the result of the distillation of seven metalline acetates in a state of purity.

	Acetate of Silver.	Acetate of Nickel.	Acetate of Copper.	Acetate of Lead.	Acetate of Iron.	Acetate of Zinc.	Acetate of Manganese.
Loss by the fire,	0.36	0.61	0.64	0.37	0.49		0.55
Residue in retort.	Reduced.	Reduced.	Reduced.	Reduced.	Black oxide.	White oxide.	Black oxide.
	0.05	0.14	0.055	0.04	0.03	0.05	0.035
Liquid products.	Sp. Gravity.	1.0398	1.0556	0.9407	1.012	0.8453	0.8266
	Proport. of acid.	107.309	84.868	3.045	27.236	2.258	1.285
	Spirituous liquor.	0	0.17	0.555	0.24	0.695	0.94
Gaseous products.	Carbonic acid	8	10	20	18	16	20
	Carb. hydrogen.	12	34	8	34	18	32
	Total of gas.	20	44	28	52	44	52

Book II.  
Division II.

The acetates of potash and of soda give a greater proportion of pyro-acetic spirit than any of the metallic acetates. When acetate of barytes is distilled, the whole liquid product consists of this spirit without any mixture of acid whatever.

Pyro-acetic  
spirit.

This pyro-acetic spirit is quite the same in its properties, from whatever acetate it is procured. No other genus of salts tried, as the oxalates, tartrates, citrates, yield this spirit. Acetic acid is not converted into it by heat. Mr Chenevix distilled the same proportion of acetic acid five or six times through a red-hot porcelain tube; part of it was decomposed, the liquor became brown, and its specific gravity was diminished, but a considerable proportion remained unaltered. But if charcoal be put into the porcelain tube, the acid is destroyed by one distillation, and nothing obtained but water, carbonic acid, and heavy inflammable air.

Its properties.

Pyro-acetic spirit is a white and limpid liquid. Its taste is at first acrid and hot, but it becomes cooling, and in some sort urinous. Its smell is peculiar, and is compared by Mr Chenevix to that of a mixture of oil of peppermint and bitter almonds. Its specific gravity, when as pure as possible, is 0.7864. It burns with a flame, white exteriorly, but of a fine blue within, and leaves no residue. It boils at the temperature of 165°. It mixes with water, alcohol, and volatile oils in any proportion. With hot olive oil also it mixes in any proportion; but with that oil cold it mixes only in certain proportions. It dissolves a little sulphur and phosphorus, and is an excellent solvent of camphor. When hot it dissolves wax and tallow. A portion of these substances precipitates as the solution cools, but water still occasions a considerable precipitate in it. It dissolves potash, and becomes darker coloured; but it may

be obtained by distillation again unaltered. When mixed with sulphuric acid it blackens and is decomposed, and much charcoal is formed. When mixed with nitric acid it becomes yellow, and its properties are altered. Some oxalic acid is formed. Muriatic acid renders it brown. When distilled with this acid a combination takes place, and a substance is formed, possessing very different properties from muriatic ether. Thus it appears that pyro-acetic spirit is a liquid possessing properties peculiar to itself, and quite different from those, both of alcohol, ethers, and volatile oils. It deserves, of course, a peculiar place among compound combustibles.

#### VI. Benzoic Acid.]

FOURCROY and Vauquelin some time ago announced, that benzoic acid might be obtained from the urine of herbivorous animals. Advantage has been taken of this discovery, and a benzoic acid, obtained from the urine of cattle, introduced into commerce in France. It has the colour and lightness of common benzoic acid, but it wants its aromatic smell. Fourcroy and Vauquelin have ascertained, that if it be mixed with about  $\frac{1}{10}$ th of its weight of benzoin in powder, and sublimed a second time, it acquires the smell and all the other properties of common benzoic acid \*.

#### VII. Sacclactic acid.

TROMMSDORF has lately subjected this acid to distil- ]

---

\* *Ann. de Chim.* lxi. 311.]



Book II.  
Division II.

lation, and examined the products. During the process the acid swells, blackens, and melts; a liquid passes into the receiver, at first colourless, then yellow, accompanied with heavy white vapours, and followed by a little empyreumatic oil; carbonic acid gas is disengaged, mixed with a little heavy inflammable gas. At the end of the process a brown transparent liquid is found in the receiver, mixed with a number of crystals. A quantity of charcoal remains in the retort, which is of the metallic lustre, and which, when incinerated, leaves traces of lime. The liquid in the receiver contains acetic and pyroluturic acids, but no traces of prussic acid or ammonia. The crystals possess the properties of succinic acid \*.

#### VIII. Suberic Acid.

CHEVREUL has lately subjected suberic acid to a new examination, and has added considerably to our knowledge of its properties. He obtained it by digesting 1 part of cork in 6 parts of acid. After the acid had ceased to act, the whole was evaporated to the consistence of an extract, hot water was poured over, and the mixture was digested for some time in a sand bath. When set aside, a matter like wax formed on the surface, and white tasteless flocks precipitated to the bottom. These substances were separated, and the liquid concentrated by evaporation. Suberic acid precipitated in powder, and towards the end of the process crystals of oxalic acid formed. I observed the formation of

\* *Ann. de Chim.* lxxi. 79.



oxalic acid some years ago, while treating cork with nitric acid. Chap. II.

Suberic acid thus formed may be purified by washing it in cold water. It is then white like starch, and has an acid taste without any bitterness. Light does not alter its whiteness. Water, at the temperature of  $140^{\circ}$ , dissolves  $\frac{1}{18}$ th of its weight of this acid, and  $\frac{1}{10}$ th at the temperature of  $55.5^{\circ}$ . When heated it melts, and on cooling crystallizes in needles. When heated in a retort it is volatilized, and condenses on the upper part in long needles. It does not precipitate lime, barytes, or strontian water, nor the salts containing these alkaline earths. The alkalis dissolve it very well, and form with it neutral salts. It precipitates nitrate of silver, muriate of tin, sulphate of iron, nitrate and acetate of lead, and nitrate of mercury, but it does not precipitate sulphate of copper or sulphate of zinc.

Nitric acid has no action on it. It dissolves in alcohol. It does not alter the colour of sulphate of indigo, provided it is free from yellow bitter matter\*. These properties show a strong resemblance between this acid and the benzoic, though it differs in several respects.

#### IX. Prussic acid.

It has been announced in the Philosophical Magazine, that Mr Porret, junior, has obtained an acid differing from the prussic in containing less oxygen, and which is converted into prussic acid by the addition of oxygen. He calls it *prussous acid*. It is a most deli-

---

\* Nicholson's Jour. xliii. 149.

Book II.  
Division II.

cate test of the presence of silver, and precipitates iron red \*. As these experiments have not yet been published, it is impossible to form any notion of their nature. If they prove accurate, they will demonstrate that oxygen is one of the constituents of prussic acid.

### X. Pyrotaric acid.

THE observation made by Gehlen respecting this acid, mentioned in vol. ii. p. 353 of this Work, induced Fourcroy and Vauquelin to examine it again, and they have ascertained that it is not an empyreumatic acetic acid, as they had been led to suppose, but an acid possessed of peculiar properties, and entitled to rank as a species apart. They obtained it by distilling tassar in a retort, saturating the liquid obtained by means of carbonate of potash, and purifying the salt by repeated crystallizations and solutions. When this salt was mixed with diluted sulphuric acid, and subjected to distillation, it furnished, towards the end of the process, a white sublimate, which attaches itself to the whole surface of the retort in scales. This sublimate is pure *pyrotartaric acid*.

Its taste is extremely acid. When heated it melts, and sublimes in a white smoke, without leaving any residue. It dissolves readily in water, and crystallizes again when subjected to spontaneous evaporation. It does not precipitate acetate of lead nor nitrate of silver, but it precipitates nitrate of mercury. Some time after

it has been mixed with acetate of lead, needleform crystals make their appearance.

Chap. II.

When combined in excess with potash, no salt similar to tartar is formed. In this state it instantly forms a precipitate when dropt into acetate of lead. Pyrotartrate of potash is soluble in alcohol. It does not precipitate the salts of barytes and lime, as tartrate of potash does\*.

## XI. Zingiberic acid.

AN anonymous writer in Nicholson's Journal † has announced the formation of a new acid from ginger, to which he has given the name of *zingiberic acid*. An ounce of white ginger was infused for two or three days in six ounces of nitric acid. The mixture was then diluted with rather more than its bulk of water, and evaporated at  $212^{\circ}$ , till the smell of nitric acid was gone. Carbonate of lead was then added to saturation, and the solution filtered. A sufficient quantity of nitric acid to neutralize the lead was added, and the liquid again filtered.

By evaporating the liquor, an acid was obtained, similar in appearance to short white pieces of raw silk. It oxidizes zinc and iron, dissolves the alkalies and alkaline earths, and the oxides of zinc, iron, lead, and copper. It differs from most of the vegetable acids, in forming soluble salts with barytes and lime. It is not volatilized nor melted at the temperature of  $212^{\circ}$ . It is pretty soluble in water. Its combination with mag-

\* *Ann. de Chim.* lxiy. 42.

† Vol. xiii. p. 384.



Book II.  
Division II.

nesia has a sweet taste. A more complete investigation will be necessary before the peculiar nature of this substance can be considered as fully established.

CHAP. IV.—SECT. II. ETHER.—Vol. II. p. 439.

Alcohol  
unites with  
all vegeta-  
ble acids.

THENARD has ascertained by experiment, that none of the vegetable acids are capable of forming an ether, when distilled with alcohol, except the acetic; but that all of them are capable of combining with alcohol, and of forming with it a kind of oily compound, if they be mixed with alcohol, and with a portion of any of the powerful mineral acids, as the sulphuric or muriatic, and distilled. The oily compound is sometimes obtained in the receiver, sometimes it remains in the retort.

Two parts of benzoic acid were dissolved in four parts of alcohol, of the specific gravity 0.800, and the solution mixed with one part of concentrated muriatic acid. This mixture was distilled in a retort. No gaseous substances were disengaged. The first liquid that came over was a weak alcohol. The last liquid that came over contained the peculiar oily substance, which might be separated by means of water. A good deal of the same matter remained in the retort, and was deposited on cooling. When purified, by washing it with hot water, in which it is not sensibly soluble, it possesses the following properties:

Its colour is yellowish; it is a little heavier than water; its taste is strong; it melts at the temperature of 80° or 85°, is volatilized at the temperature of 170°; is



acid, oily, scarcely soluble in cold water, more soluble in boiling water, but precipitates as the liquid cools; very soluble in alcohol, from which it may be precipitated by water. When deprived of the excess of benzoic acid by an alkaline carbonate, it became colourless, and remained liquid at the common temperature of the atmosphere; its other properties remained the same. When long agitated with caustic potash, it was decomposed, and found to be a compound of benzoic acid and alcohol.

A mixture of 30 parts oxalic acid, 36 alcohol, and 10 of sulphuric acid, being distilled till sulphuric ether begins to come over, the liquid in the retort, when diluted with water, deposited a similar oily matter, which was a compound of oxalic acid and alcohol. Citric and malic acids being substituted for oxalic, a similar oily compound was obtained. Tartaric acid furnished also an oily compound, but its properties were peculiar. Traces of a similar compound were observed when gallic acid was employed. The other vegetable acids were not tried; but it is probable that they also would furnish similar compounds: so that alcohol seems to have the property of combining with almost all the acids, and of neutralizing them, and concealing their characteristic properties.

When concentrated sulphuric acid is added to a mixture of acetic acid and alcohol, it greatly facilitates the formation of acetic ether. Nitric and muriatic acids produce the same effect, but a greater proportion of them is necessary. Phosphorous acid likewise produces a considerable effect, and arsenic and oxalic acids a still less. Tartaric and phosphoric acids produce no effect whatever. Thus it appears that acids favour the form-

Book II.  
Division III.

ation of acetic ether in proportion as they have property of condensing alcohol \*.

Thénard has endeavoured to show that all animal vegetable substances have the property of combining with acids, and of neutralizing them. He has produced five examples from vegetable bodies, and as many from the animal kingdom. His hypothesis is ingenious though he has probably stretched it a great deal far †.

BOOK II.—DIVISION III.—CHAP. III. SALTS.

Vol. II. p. 565.

SEVERAL valuable analyses of different salts have appeared since this Chapter was printed. The following Tables include the most material of these :

Muriate of Potash.

	†	‡
Acid	34.83	33.34
Base	65.17	66.66
Total	100	100

\* *Mém. d'Arcueil*, ii. 5.

† *Ibid.* ii. 23.

‡ *Curadon, Jour. de Phys.* lxvii. 21.

§ *Berthollet, Mém. d'Arcueil*, ii. 55.

## Muriate of Soda.

Chap. III.

	*	†
Acid	46	43
Base	54	57
Total	100	100

## Muriate of Ammonia.

61.65 acid

38.35 base

100 †

## Muriate of Magnesia.

56.01 acid

43.99 base

100 §

## Muriate of Lime.

49.23 acid

50.77 base

100 ||

\* Dr Marcet, Nicholson's *Jour.* xx. 30.† Berard, *Ann. de Chim.* lxxi. 65.‡ Gay Lussac, *Mém. d'Arcueil*, ii. 253. His method was the same as mine; but I fell into an error, from not knowing the quantity of water in muriatic acid gas.§ Marcet, Nicholson's *Jour.* xx. 29.

|| Ibid.

Phosph

Carbo

Subcar

Carb

\* Berthollet, *Mém. d'Ar*† Berard, *Ann. de Chim.*§ 14. *Ibid.* p. 55.



## Subcarbonate of Soda.

Chap. III.

	*	*	†
Acid	13.98	37.47	16.04
Base	23.33	62.53	20.85
Water	62.69		63.61
Total	100	100	100

## Carbonates of the Alkaline Earths.

BERTHOLLET has rendered it probable, that what are considered at present as carbonates of the alkaline earths, are in reality subcarbonates; and that the true carbonates, if they could be formed, would contain twice as much acid, united to the same quantity of base, as the known carbonates §.

## Sulphate of Potash.

		¶	**
Acid	41.50	42.29	42.76
Base	58.50	57.71	57.24
Total	100	100	100

\* Berard, *Ann. de Chim.* lxxi. 55 and 58.† D'Arcet, *Ibid.* lxxiii. 178, and lxxi. 203.§ *Mém. d'Arcueil*, ii. 478.|| Bertholler, *Ibid.* p. 62.¶ Curaudan, *Jour. de Phys.* lvii. 10.\*\* Berard, *Ann. de Chim.* lxxi. 47.

Book II.  
Division III.

## Sulphate of Soda.

22.78 acid

47.22 base

---

 100.00 \*

## Sulphate of Barytes.

32.30 acid†

67.70 base

---

 100.00 †

## Nitrate of Potash.

	‡	§	
Acid	48.62	50.24	51.36
Base	51.38	49.76	48.64
Total	100	100	100

## Phosphates.

It has been the opinion of chemists, that the only phosphates which can be decomposed by heat and charcoal, are the phosphate of ammonia and the metalline

---

\* Berard, *Ann. de Chim.* lxxi. 54.

† Berthollet, *Mém. d'Apucil*, ii. 49.

‡ Id. Ibid. p. 59.

§ Curtaudau, *J. Nr. de Phys.* lxxvii. 10.|| Berard, *Ann. de Chim.* lxxi. 68.

phosphates. Saussure junior has shown that this opinion is erroneous. By distilling a mixture of phosphate of potash and charcoal, and phosphate of soda and charcoal, in a strong heat, he obtained a considerable quantity of phosphorus. Even phosphate of lime was decomposed by the same process, but a very violent temperature was necessary\*.

#### Sulphate of Copper.

PRIEUR has observed, that the sulphate of copper, when sufficiently transparent, refracts doubly, like many other crystals of a similar form†.

#### BOOK III.—CHAP. II.—SECT. II. MIXTURE OF GASES. Vol. III. p. 453.

THE experiments of Mr Dalton upon the rapidity with which gases mixed when brought into contact, have been repeated with care by Berthollet. His apparatus consisted of two small globular glass vessels, furnished each with a stopcock; the capacity of the first was 1.591 cubic inches, that of the second 1.693 cubic inches. They were joined by a tube 0.197 inch in diameter, and 10.43 inches long. The experiments were made in a cellar, where the temperature was equable. The stopcocks were kept shut, and all communication prevented, till the vessels had acquired exactly the same

\* *Ann. de Chim.* lxxv. 189.

† *Ann. de Chim.* lxxvi. 188.

Book III.

temperature. The stopcocks were then opened, the proper precautions not to alter the temperature at the end of the experiment, the stopcocks were closed and the gases in each vessel examined. The following table exhibits the result of these experiments.

Glass vessels.	Gases used.	Time.	Gases found in
1 2	Hydrogen Carbonic acid	48 hours	41.73 Car. a. 43.26 Ditto
1 2	Hydrogen Air	48 hours	47.24 Hydrog. 47.62 Ditto
1 2	Hydrogen Carbonic acid	24 hours	43 Carbonic 46 Ditto
1 2	Air Carbonic acid	24 hours	28 Carbonic 56 Ditto
1 2	Air Carbonic acid	24 hours	27.2 Carbonic 59.8 Ditto
1 2	Azotic Oxygen	24 hours	60 Oxygen 39.33 Ditto
1 2	Hydrogen Oxygen	24 hours	50 Oxygen 50 Ditto
1 2	Hydrogen Azotic	24 hours	46 Hydrogen 45 Ditto
1 2	Azotic Carbonic acid	24 hours	22 Carbonic 60 Ditto
1 2	Azotic Carbonic acid	48 hours	35 Carbonic 61 Ditto



Glass vessels.	Gases used.	Time.	Gases found in each vessel.
1 2	Oxygen Carbonic acid	24 hours	24 Carbonic acid 60 Ditto
1 2	Air Carbonic acid	17 days	42 Carbonic acid 50 Carbonic acid

From these experiments it appears, that the gases mix more speedily when one of them is hydrogen, and much more slowly when that gas is wanting. In the last experiment we see, that 17 days were not sufficient to produce an equable mixture of air and carbonic acid \*. It is unnecessary to observe, how incompatible these results are with Mr Dalton's hypothesis of the non-elasticity of different gases with respect to each other.

### SECT. III. COMBINATION OF GASES.

Vol. III. p. 467.

GAY LUSSAC has published an ingenious essay † on the combination of gases, in which he has endeavoured to show, that they always combine either in equal bulks, or one part of one, by bulk, with two or with three parts of the other. Though he appears to me to have carried his generalization rather too far, yet it must be allowed, that in a good many of the cases he has made out his point. The following table exhibits

\* *Mém. d'Arcueil*, ii. 463.

† *Ibid.* ii. 207.

As the specific gravities of the different gases which Gay Lussac employed, differ a good deal from some of those which I have given, I think it necessary to add them here, together with the names of the philosophers who made the experiments. At the same time, I do not consider them as so correct as those which I have given in the table, Vol. III. p. 439, of this work.

Gases.	Sp. gravities.	Authorities.
Air .....	1·00000	Biot and Arrago
Oxygen gas .....	1·10359	
Azotic gas .....	0·96913	
Hydrogen gas .....	0·07321	
Carbonic acid gas ....	1·51961	
Ammoniacal gas ....	0·59669	Biot and Gay Lussac
Muriatic acid gas ....	1·278	
Nitrous oxide .....	1·61414	Davy
	1·36293	Berthollet
Nitrous gas .....	1·0388	Berard
Sulphurous acid gas	2·265	Kirwan
Carbonic oxide .....	0·9569	Cruikshanks
Steam .....	0·6896	Trales
Oxymuriatic acid gas	2·470	Thenard & Gay Lussac

## PART II.—BOOK I.—CHAP. I.—SECT. I. AIR.

Vol. IV. p. 6.

GAY LUSSAC has published some observations upon the nitrous gas endiometer, which differ very much from those of Dalton, stated in p. 14 of this section. According to Gay Lussac, oxygen gas combines with two proportions of nitrous gas, either with twice or

Part II.  
Book I.

with thrice its bulk of it. When the oxygen predominates, the compound formed consists of one part oxygen, and two parts nitrous gas; when the nitrous gas predominates, the compound formed consists of one part oxygen, and three parts nitrous gas. To analyse air, let up 100 measures of it into a wide vessel; add 100 measures of nitrous gas; do not agitate. In about a minute the absorption is complete. Measure the residue. One fourth of the bulk absorbed gives the oxygen gas in the air examined \*. I have repeated this experiment, and find, that unless the vessel be 3 inches in diameter, the result is very inaccurate. Even then, one fourth of the bulk absorbed hardly equals the quantity of oxygen in the air. Hence it is obvious that a vessel of 5 or 6 inches in diameter is necessary to ensure an approach to correct results, when the experiment is made in that way.

PART II.—BOOK I.—CHAP. II.—SECT. VI.  
METEORIC STONES. Vol. IV. p. 119.

IN the account of the constituents of meteoric stones, it was omitted to mention, that Laugier has detected chromium as a constituent of them, and that this substance has been found in small quantities in most meteoric stones analysed since that discovery was announced.

Sage affirmed, that he had discovered alumina as another constituent; but when Vauquelin repeated the

---

\* *Mém. d'Arcueil*, ii. 235.



experiment, he could only find minute traces of that earth. But a meteoric stone, which fell lately in Moravia, and which has the common characters of other meteoric stones, has been found to possess different constituents. The following is the analysis of it by Vauquelin.

Silica .....	50
Lime .....	12
Alumina .....	9
Oxide of iron .....	29
Oxide of manganese ...	1
Nickel, a trace	
Sulphur, an atom	

---

101

The presence of lime and alumina, and the absence of magnesia and chromium, distinguish this stone from all others formerly examined, and constitute it a species apart.

#### PART II.—BOOK III. MINERALS. Vol. IV. p. 161.

A CONSIDERABLE number of new chemical analyses of minerals have been recently published, chiefly by Klaproth. I shall here insert the most important of these, following the order in which the minerals themselves have been arranged.



## Part II.

## Cinnamon Stone.

Silica .....	38·80
Alumina .....	21·20
Lime .....	31·25
Oxide of iron .....	6·50
Loss .....	2·25
	<hr/>
	100·00 *

From this analysis it is obvious, that cinnamon stone is improperly classed with zircon and hyacinth. Professor Jameson had previously placed it in the garnet family, considering it as the hyacinth originally analysed by Bergman.

## Augite of Frascati.

Silica .....	48·00
Lime .....	24·00
Magnesia .....	8·75
Alumina .....	5·00
Oxide of iron .....	12·00
Oxide of manganese	1·00
Loss .....	1·25
	<hr/>
	100·00 †

\* Klaproth, *Ann. de Chim.* lxx. 186.† Id. *Ibid.* lxxii. 225.

The specific gravity of the specimen was 3.400. Book III.  
 This analysis corresponds with the preceding, except in  
 the proportion of lime, which is greater.

	Green- land Garnet.	Melanite of Frascati.	Granatite.	
	*	†	‡	§
Silica	43.00	35.50	37.50	27.00
Alumina	15.50	6.00	41.00	52.25
Lime	1.75	32.50		
Magnesia	8.50		0.50	
Iron oxide	29.50	24.25	18.25	1.50
Manganese oxide	0.50	0.40	0.50	0.25
Loss	1.25	1.35	2.25	2.00
	100.00	100.00	100.00	100.00

## Schorlite.

	§	
Silica	36.8	43.0
Alumina	52.6	49.5
Lime	3.9	
Oxide of iron		1.0
Fluoric acid	5.8	4.0
Water	1.5	1
Loss		1.5
	100.0	100.0

\* Klaproth, *Ann. de Chim.* lxx. 186.

† Id. *Ibid.* lxxii. 233. Sp. gr. 3.7

‡ Id. *Ibid.* p. 235. First variety black, second red.‡

§ Vauquelin, *Ibid.* lxxii. 247.

|| Klaproth, *Ibid.* p. 250.

## Part II.

	Quartz crystals.	Amorph. Quartz.	Prase.	Iron sim.		
	•	•	•	†	†	†
Silica	99.37	97.75	98.5	92.00	93.5	90.0
Alumina	0.63†	0.50†	0.5			0.25
Oxide of iron			1.0	5.75	5.	21.5
Ox. of man.				1.00		
Water		1.00		1.00	1.	1.0
Loss		0.75		0.25	0.5	1.75
	100.	100.	100.	100.	100.	100.

## Mica.

	§	§	§
Silica	47.00	48.00	42.5
Alumina	20.00	34.25	11.5
Magnesia		0.50	9.0
Oxide of iron	15.50	4.50	22.0
Oxide of manganese	1.75		2.0
Potash	14.50	8.75	10.0
Water		1.25	1.0
Loss	1.25	2.75	2.0
	100	100	100

\* Bucholz, *Ann. de Chim.* lxx. 49.

† Id. *Ibid.* p. 55. The first variety brown, the second yellow, the third red.

‡ A mixture of alumina and oxide of iron.

§ Klaproth, *Ann. de Chim.* lxx. 98, 113, and 120. The first specimen was common mica, the second broad-leaved mica from Siberia, the third black mica from Siberia.

## Labradore Hornblende.

Rock III.

54.25 silica
2.25 alumina
1.50 lime
14.00 magnesia
24.50 oxide of iron
1.00 water
2.50 loss

100.00 \*

has lately made this mineral a distinct species,  
 he distinguishes by the name of *hyperstene*.

	Common Talc.	Scaly Talc.
	†	‡
Silica	62.00	
Alumina		81.75
Lime		4.00
Magnesia	30.50	0.75
Oxide of iron	2.50	
Potash	2.75	0.50
Water	0.50	13.50
Loss	1.75	
	100.00	100.50

from these analyses it is obvious, that these two mi-  
 ls ought to be separated from each other, and no  
 er considered as belonging to the same species.

Klaproth, *Ann. de Chim.* lxxvii, 241.† *Id.* *Ibid.* lxx. 100.John, *Ibid.* lxxvii, 259.



## Part II.

	Calcareous Spar.	Arragonite.
	•	•
Lime	56.327	56.351
Carbonic acid	43.045	42.919
Water	0.628	0.730
	100.000	100.000

## Capillary Pyrites.

KLAPROTH has analysed this ore, and found it same nickel with some cobalt and arsenic. It must, of course, be separated from iron pyrites, with which it has a connection †.

## Sulphate of Cobalt.

THE mineral described under this name, in Vol. IV. p. 507, it appears, is rather a sulphate of magnesia mixed with oxide of cobalt. But real sulphate of cobalt has been lately found at Bieber in the county of HANNO. It is thus described by Kopp.

Colour flesh red, passing to rose red and carmine red. Sometimes dendritiform, and sometimes in thin layers on other minerals. Lustre usually 0, sometimes 2, silky. Fracture earthy. Opaque. Streak reddish white. Soft. Light. Taste styptic. It occurs cover-

\* Thenard and Biot, *Mém. d'Arcueil*, ii. 176.

† *Ann. de Chim.* lxx. 186.

ing sulphate of barytes, along with other ores of cobalt. Book III.

Its constituents are,

38.71 oxide of cobalt

19.74 sulphuric acid

41.55 water

---

100.00

#### Needle Ore.

THIS mineral has been erroneously arranged among the ores of chromium. It ought to be placed among the ores of bismuth, as is obvious from the following analysis of Dr John.

43.20 bismuth

24.32 lead

12.10 copper

1.58 nickel?

1.32 tellurium?

11.58 sulphur

5.90 loss

---

100.00†

#### Aplome.

THIS is the name given by Hauy to a mineral found in Siberia, on the borders of the river Lena. It has some resemblance in its crystallization to the garnet and the vesuvian. Its crystals are dodecahedrons,

\* *Ann. de Chim.* lxi. 55.

† *Ibid.* lxvii. 278.

## Part II.

formed from a cube by a decrement of one range on each edge. Colour reddish brown. Very hard. Breaks into crystalline fragments, with difficulty reduced to powder. Specific gravity 3.444. According to the analysis of Laugier, it is composed of

40.0 silica
20.0 alumina
14.5 lime
14.5 oxide of iron
2.0 oxide of manganese
2.0 mixture of silica and iron
2.0 loss by calcination
5.0 loss

---

100.0 \*

## Bronzite.

THIS mineral has been classed by Haüy as a variety of smaragdite, under the name of *lamello-fibrous diallage*. It occurs in serpentine near Kranbat in the Upper Stiria, in large masses, and has been observed in other places disseminated in serpentine.

Colour tombac brown. Massive and disseminated. Lustre 4, semimetallic. Fracture lamellar, with a single cleavage. In distinct granular concretions. Transparency 2; in large masses 0. Streak white. Semihard. Very brittle. Specific gravity 3.200. According to the analysis of Klaproth, its constituents are as follows:

---

\* *Jour. de Phys.* lxxvii. 307. *Ann. de Chim.* lxxi. 110.



60.0 silica
27.5 magnesia
10.5 oxide of iron
0.5 water
1.5 loss
<hr/>
100.0 *

PART II.—BOOK IV.—CHAP. II.—SECT. V.  
LEAVES. Vol. V. p. 223.

Tobacco.

VAUQUELIN has lately published an elaborate analysis of the leaves of the different species of *nicotiana*, chiefly the *latifolia*. The expressed juice contained the following substances :

1. A considerable quantity of albumen.
2. Supermalate of lime.
3. Acetic acid.
4. A notable quantity of nitrate and muriate of potash.
5. A red matter soluble in alcohol and water, which swells considerably when heated.
6. Muriate of ammonia.
7. A peculiar substance, to which tobacco owes its properties. This substance is colourless, acrid, volatile, soluble in water and in alcohol, and seems different from every vegetable principle hitherto described. It seems to approach the volatile oils in many of its properties.
8. Green fecula, composed, as usual, chiefly of gluten, green resin, and woody fibre †.

\* *Ann*

† *Ibid.* lxxi. 139.



BERZELIUS has published a variety of results which he obtained by analysing animal substances. The following are the most important of these.

1. Muscular flesh contains an uncombined acid. This acid is combustible, and analogous to the malic. All the alkali contained in the liquor extracted from muscle, is saturated with this acid.

2. The fibrin and coagulable part of blood, he considers as the same substance in different states. Iron is the colouring matter of blood, but not phosphate of iron. Blood contains no gelatine, but some is formed when the blood is long boiled.

3. The acid of milk, in his opinion, is not the acetic acid.

4. He could not succeed in analysing bile by the process of Thenard. What is called resin of bile he considers as not entitled to the name of resin \*.

#### Niccolanum.

I FORGOT to mention, in its proper place, that Hisinger and Gehlen have proved that niccolanum is a compound of nickel and cobalt, with a trace of iron and arsenic †.

\* *Ann. de Chim.* lxxi. 218.

† *Jour. de Phys.* lxxviii. 29.

---

---

FINIS.

---

---



